PB-227 060

R/V ONAR CRUISES 434, 450, 469, 502. SYOPS (SYNTHETIC ORGANICS IN PUGET SOUND) CRUISE SERIES 1, 2, 3, 4. HYDROGRAPHIC, CHEMICAL AND BIOLOGICAL MEASUREMENTS

S. P. Pavlou, et al

Washington University

Prepared for:

Environmental Protection Agency

December 1973

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

031059

U.S. ENVIRONMENTAL PROTECTION AGENCY

NATIONAL COASTAL POLLUTION RESEARCH PROGRAM

Data Report

R/V ONAR CRUISES 434, 450, 469, 502

HYDROGRAPHIC, CHEMICAL AND BIOLOGICAL MEASUREMENTS

Special Report No. 54
Department of Oceanography
University of Washington
Seattle, Washington 98195

PB 227 060

University of Washington
Department of Oceanography
Seattle, Washington 98195

DATA REPORT

R/V *ONAR* Cruises 434, 450, 469, 502
SYOPS (Synthetic Organics in Puget Sound) Cruise Series 1, 2, 3, 4
Hydrographic, Chemical and Biological Measurements

Compiled by

S. P. Pavlou, K. A. Krogslund, R. N. Dexter and J. R. Clayton

United States Environmental Protection Agency
Grant No. R-800362
Principal Investigator: S. P. Pavlou

Special Report No. 54
December, 1973
Reference No. M73-81

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

TABLE OF CONTENTS

CRUISE PARTICIPANTS.....iii

INTRODUCTION.....1

Plan of Research
Hydrographic Sampling and Chemical Methods
Biological Methods
Sampling Methods for Chlorinated Hydrocarbons
Analysis for Chlorinated Hydrocarbons
Trace Metals
References

STATION LOCATIONS.....9

STATION LOGS.....17

HYDROGRAPHIC, CHEMICAL AND BIOLOGICAL DATA (SYOPS 1, 3).....23

PRODUCTIVITY DATA (SYOPS 1, 3).....39

SALINITY, TEMPERATURE, DEPTH PROFILES (SYOPS 1, 3).....53

SPATIAL DISTRIBUTION OF VARIABLES.....77

(T, S, σ_T, DO, nutrients, PN, PC, Chlorophyll, ETS, protein)

SYOPS-1.....77

Horizontal Contour Plots
Vertical Contour Plots
St 06-12-18-19 transect
St 16-17-19-20 transect

SYOPS-3.....127

CHLORINATED HYDROCARBON DATA.....137

Sediments (SYOPS 2, 3, 4)
Zooplankton (SYOPS 4)

TRACE METALS (SYOPS-1).....151

APPENDIX I: SAMPLING METHODOLOGY FOR CHLORINATED HYDROCARBONS.....155

A Description of the Large Volume Filter
A Zooplankton Net for Excluding Surface Film Components
References

APPENDIX II: ANALYTICAL METHODOLOGY FOR CHLORINATED HYDROCARBONS.....165

Preanalysis Processing
Analysis
References

CRUISE PARTICIPANTS

Investigator	Cruise No.	Institution	Title	Project
		Research Staff		
Blazevich, J. N.	(2, 3, 4)	EPA(NERC)	Research Chemist	Sediments
Clayton, J. R.	(1, 2, 3, 4)	U of W	Research Asst.	Zooplankton, DO
Dexter, R. N.	(1, 2, 3, 4)	U of W	Research Asst. (Cruise Leader)	Phytoplankton routine chemistry hydrography, sediments
Krogslund, K. A.	(1, 3)	U of W	Research Asst.	Chlorophyll, PN, PC
Pavlou, S. P.	(1, 2, 3)	U of W	Res. Asst. Prof. (Chief Scientist)	Hydrography, sediments
Sainsbury, J. P.	(4)	EPA(R-10)	Chemist	Sediments
Cummins, J.	(4)	EPA(R-10)	Biologist	Sediments
Reich, R.	(4)	EPA(R-10)	Chemist	Sediments
		Technical Staff		
Moore, T.	(1)	U of W	Research Tech.	Phytoplankton, ETS, Protein
Owens, T.	(1)	U of W	Research Tech.	Zooplankton, ETS, Protein
Piety, J.	(1)	U of W	Marine Tech.	Hydrography, routine chemistry
Burns, G.	(4)	EPA(R-10)	Technician	Sediments

Data Report - R/V ONAR Cruises 434, 450, 459, 502
SYOPS (Synthetic Organics in Puget Sound)
Cruise Series 1, 2, 3, 4, Hydrographic,
Chemical and Biological Measurements

Compiled by S. P. Pavlou, et al.

ERRATA

Page 141 — ΣDDT/PCB values for Stations 6, 21 and 23 should be changed to 0.016, 0.009 and 0.118 respectively. The ΣDDT value for station 23 should be corrected to 7.66.

Page 142 — Change footnote *a* from micrograms per gram of dry weight to micrograms per kilogram of dry weight.

Page 153 — Change *Zn* to *Pb*.

The SYOPS cruise series was initiated in September 1972 as the baseline field component of a general project to determine the distribution and biological consequences of chlorinated hydrocarbons and other trace organic compounds of environmental significance in Puget Sound and its major subregions (Figure 1). For SYOPS 1, 2 and 4 sampling was concentrated in Elliott Bay and included sampling of the Duwamish River in conjunction with the EPA's Region-10 studies on sediments. Some reference stations were also taken in the main basin (Figures 1, 2 and 3). SYOPS-3 covered some of the southern sub-regions of Puget Sound, including Commencement Bay (Figure 4), Budd Inlet and Oakland Bay (Figure 5). This extensive sampling program is being continued. At present, northern regions of the Sound receiving substantial loads of industrial and municipal wastes are being examined. Future field programs will involve time series data gathering under low and high tidal fluctuations, for varying surface runoff conditions, in areas where large trace organic gradients have been observed.

Plan of Research

Station grids were prepared covering all of Elliott Bay and a major portion of Commencement Bay. Stations were taken approximately in the middle of smaller bays, inlets, and passages. Sampling included standard hydrography (T, Salinity, DO), nutrients, particulate nitrogen (PN), and chlorophyll-a. Suspended particulate matter (including phytoplankton), zooplankton and sediments were collected for chlorinated hydrocarbon analyses. In addition, SYOPS-1 included sampling for particulate carbon (PC), particulate protein, respiratory electron transport activity (ETS) for phytoplankton and zooplankton, and for trace metals.

Hydrographic Sampling and Chemical Methods

Hydrographic casts were made using modified 6-liter plastic Scott-Richards bottles. Standard oceanographic sample collection and handling procedures were followed. Samples were routinely collected at depths of 0, 5, 10, 15 and 30 meters. At shallow stations, only the upper depths of the series were taken.

Oxygen concentrations were determined by a modified Winkler method (Carpenter, 1966). Salinities were measured in the laboratory with a Washington bridge salinometer. Nutrient samples were frozen immediately after collection and analyzed by an automated technique for ammonia, nitrate, reactive silicate and reactive phosphate, as described by Friederich and Whitledge (1972).

Biological Methods

Samples for PN, PC, Chlorophyll-*a*, ETS and protein analysis were collected at 0, 3, 6, 15 and 30 meters on SYOPS-1, and at 0, 10 and 30 meters on SYOPS-3. SYOPS-1 samples were taken with a 40 liter PVC sampler, approximately 2 m long, at depths of 15 and 30 meters. Samples from 0, 3 and 6 meters and the intersation surface samples were taken using a rotary pump, with the intake hose placed at the required depth. On SYOPS-3, samples were collected using Scott-Richards bottles as described earlier. Water samples for chlorophyll-*a* and PN were filtered through a 212μ netting to remove zooplankton. All samples were stored in polyethylene carboys prior to filtration.

Chlorophyll-*a* was analyzed by the SCOR-UNESCO method (1966). After filtration on Millipore(R) filters, the samples were immersed in 5 ml of acetone in a stoppered test tube, stored in a light-tight box and refrigerated for approximately 24 to 48 hours. Spectra were analyzed on a Beckman Acta-II spectrophotometer.

PN samples were filtered on 4.25 cm Reeve Angel glass fiber filters. The filters were stored in glassine envelopes and then frozen and dessicated. Samples were combusted in a Coleman nitrogen analyzer and total nitrogen was determined by manometry (Pavlou *et al.*, 1972).

The respiratory electron transport (ETS) activity in both phytoplankton and zooplankton was measured by the method of Packard (1971). Temperature corrections were applied as described by Packard, Healy and Richards (1971). Protein samples were analyzed using the method of Lowry *et al.* (1951) as described by Packard *et al.* (1972).

Sampling Methods for Chlorinated Hydrocarbons

Phytoplankton and Suspended Particulate Matter. Particulate matter was collected by filtering water through a precombusted glass fiber filter. For SYOPS-I the filter sampler consisted of a 9 cm stainless steel filter holder connected to a 1/4 inch stainless steel tube which extended 2 meters below the surface. Vacuum, to draw water through the filter, was provided by an aspirator pump. This configuration was proven inadequate and time consuming due to the low filtering capacity of the 9 cm filters (∿50 to 80 liters/hr/station). A new large volume filter (LVF) system (∿300 ℓ/hr) was designed and implemented during SYOPS 3 and 4. A brief description of the LVF is given in Appendix I. The filters were placed immediately in pre-rinsed jars with aluminum foil cap liners and frozen until analyzed.

Zooplankton. Samples were collected by a protected closed net (PCN), as described in Appendix I. Immediately after collection, the zooplankton were transferred from the cod end of the net to an eight-inch, 246μ mesh, brass sieve. The excess water was removed, the material transferred to hexane-rinsed screw-cap glass jars, and stored frozen until analysis.

Sediments. During SYOPS 1, 2 and 3 sediment samples were collected using a 4-bore hydraulic corer with stainless steel fittings and core tubes. (2.25" diameter). The cores were extruded on deck into pre-rinsed jars and frozen for later analysis. On SYOPS-4 a standard van Veen grab sampler was used for surface sediment collection.

Analysis for Chlorinated Hydrocarbons

A detailed description of the methodology for the extraction, purification and analysis of chlorinated hydrocarbon residues from the biological and sediment samples is included in Appendix II. A brief summary is given below.

Suitable aliquots of the samples were extracted with organic solvent; the chlorinated hydrocarbons were isolated from the extract, cleaned up, condensed and then analyzed on a Microtek MT-220 gas chromatograph equipped with a ^{63}Ni high temperature electron capture detector. In certain cases PCB and pesticide components were confirmed by mass spectrometry on a Finnegan Model 1015C GC/MS system at the NERC Laboratories, Corvallis, Oregon.

Trace Metals

Seawater samples were drawn directly from Scott-Richards bottles and collected in pretreated polyethylene bottles[1] and stored frozen for later analysis.

Copper and lead were analyzed by anodic stripping voltametry using a modified system described by Matson (1968). The samples were run at pH 4.9 to maximize the response of the inorganically bound and adsorbed species to the electrode.

---

[1]The bottles were prewashed in 1:1 (v/v)HNO_3: water, rinsed three times with de-ionized water, partially filled with seawater and left to equilibrate for 48 hours.

References

Armstrong, F.A.J., C.R. Stearns and J.D.H. Strickland, 1967. The measurement of upwelling and subsequent biological processes by means of the Technicon AutoAnalyzer(R) and associated equipment. *Deep Sea Research*, 14:381-389.

Carritt, D.E. and J.H. Carpenter, 1966. Modification of the Winkler method for dissolved oxygen in seawater; a comparison and evaluation. *J. Mar. Res.*, 24:286-318.

Friederich, G.E. and T.E. Whitledge, 1972. AutoAnalyzer procedures for nutrients, in: Phytoplankton Growth Dynamics; Technical Series I - Chemostat Methodology and Chemical Analyses, S.P. Pavlou, *ed.* Special Report No. 52, Department of Oceanography, University of Washington, Seattle. 130 pp.

Koroleff, T., 1970. Information on techniques and methods for seawater analysis. *Int. Con. Explor. Sea, Interlab Rep. No. 3:* 19-22.

Lowrey, *et al.*, 1951. Protein measurement with the Tolin Phenol Reagent. *J. Biol. Chem.* 193:265.

Matson, W., 1968. Trace Metals. Equilibrium and kinetics of trace metal complexes in natural media. Ph.D. Thesis, Department of Chemistry, MIT.

Murphy, J. and J.P. Riley, 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta*, 27:31-36.

Packard, T.T., T.M. Moore and D.A. Harmon, 1972. Biochemical assays, in: Phytoplankton Growth Dynamics; Technical Series I - Chemostat Methodology and Chemical Analyses, S.P. Pavlou, *ed.* Special Report No. 52, Department of Oceanography, University of Washington, Seattle. 130 pp.

Packard, T.T., 1971. The measurement of respiratory electron transport activity in marine phytoplankton. *J. Mar. Res.* 9:235-244.

Packard, T.T., M.L. Healy and F.A. Richards, 1971. Vertical distribution of the activity of the respiratory electron transport activity in marine phytoplankton. *Limnol. Oceanogr.*, 16:60-70.

Pavlou, S.P., *ed*, 1972. Phytoplankton growth dynamics: Technical Series - Chemostat methodology and chemical analyses. Special report no. 52. Department of Oceanography, University of Washington, Seattle. 130 pp.

SCOR-UNESCO, 1966. Determination of photosynthetic pigments in seawater. Report of SCOR-UNESCO Working Group 17 (Paris): Monographs on Oceanographic Methodology, 1. 69 pp.

Slawyk, G. and J.J. MacIsaac, 1972. The specificity of an automated phenol-hypochlorite ammonium method in a region of coastal upwelling. *Deep Sea Research*, 19:521-524.

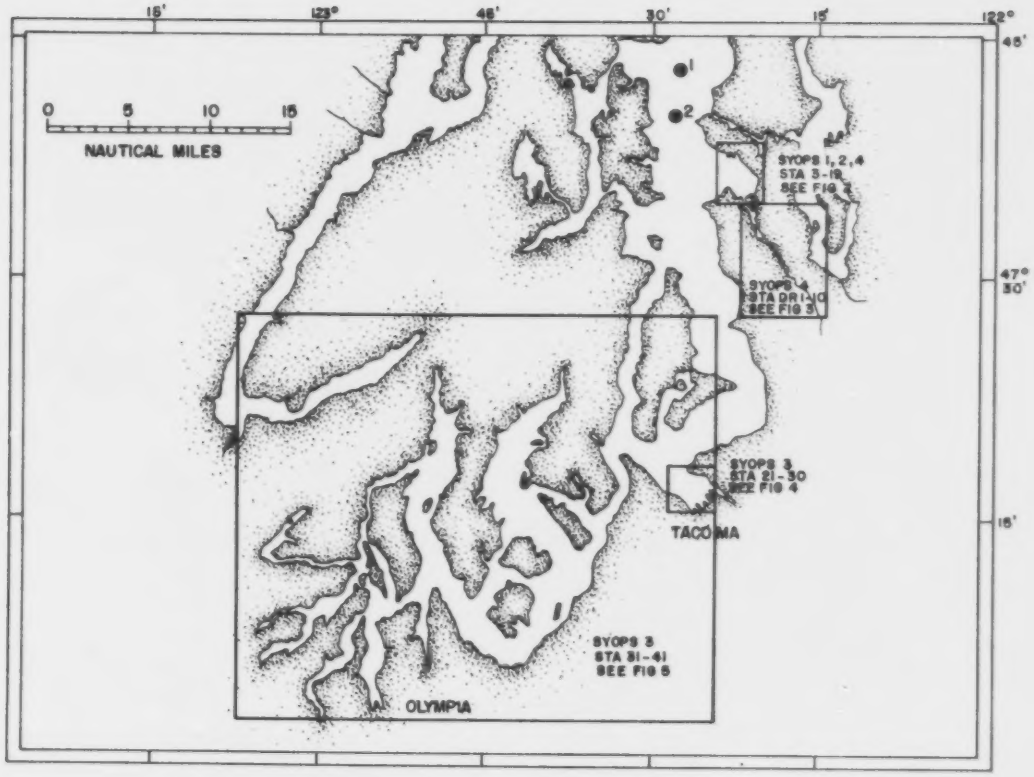


Figure 1. Location of sampling regions for SYOPS cruises 1, 2, 3 and 4

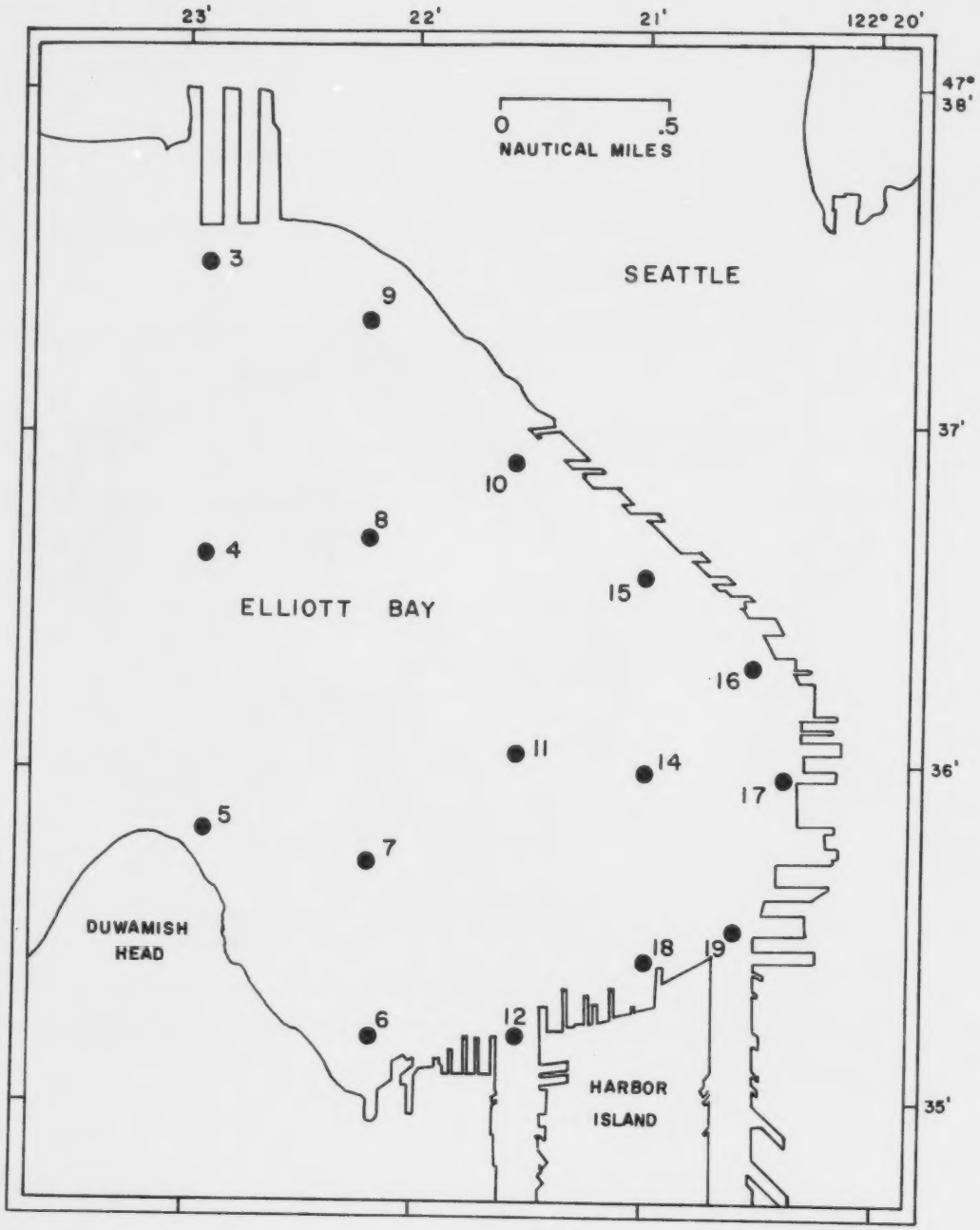


Figure 2. Station locations for SYOPS 1, 2 and 4

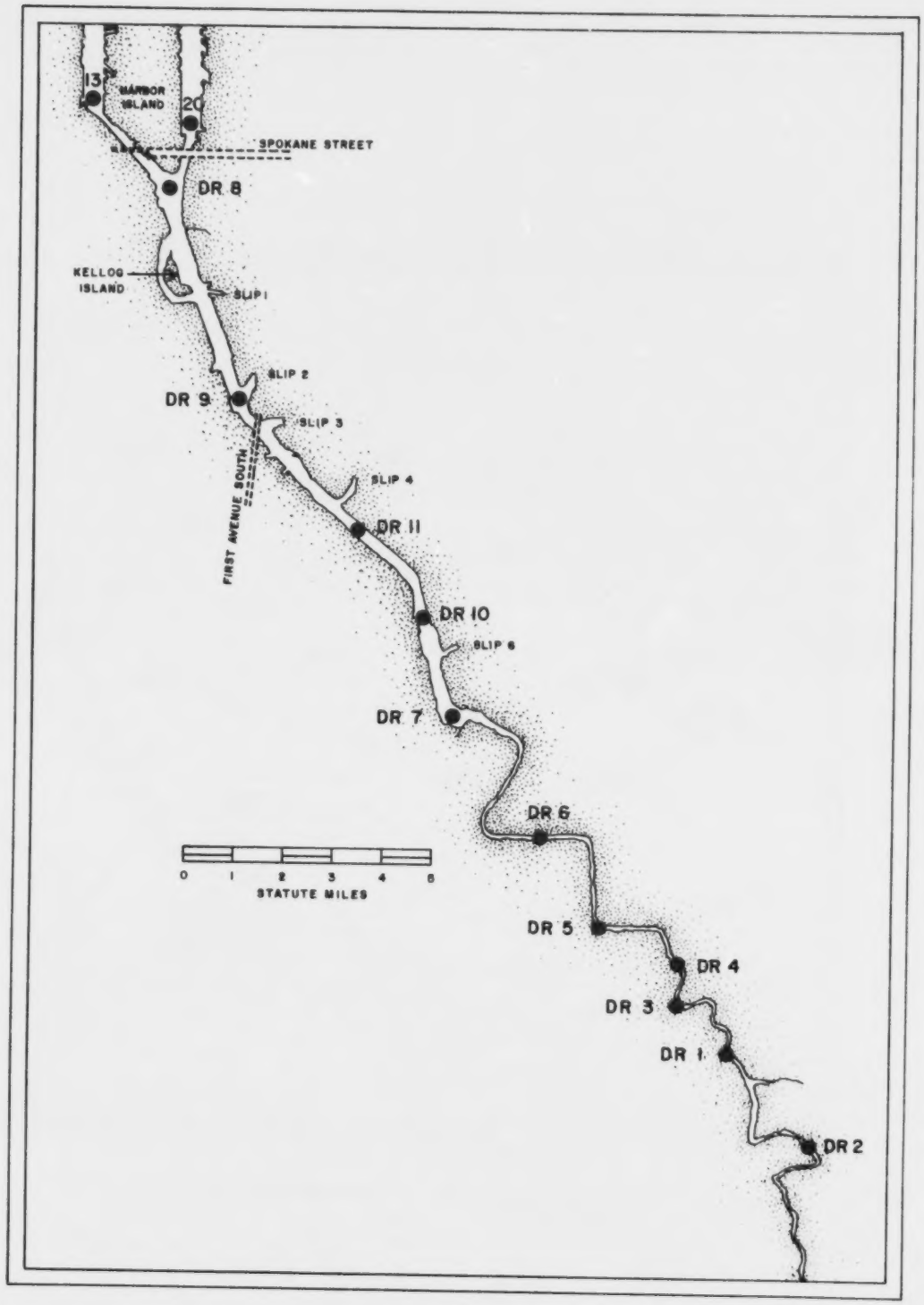


Figure 3. Station locations in the Duwamish River (SYOPS 4)

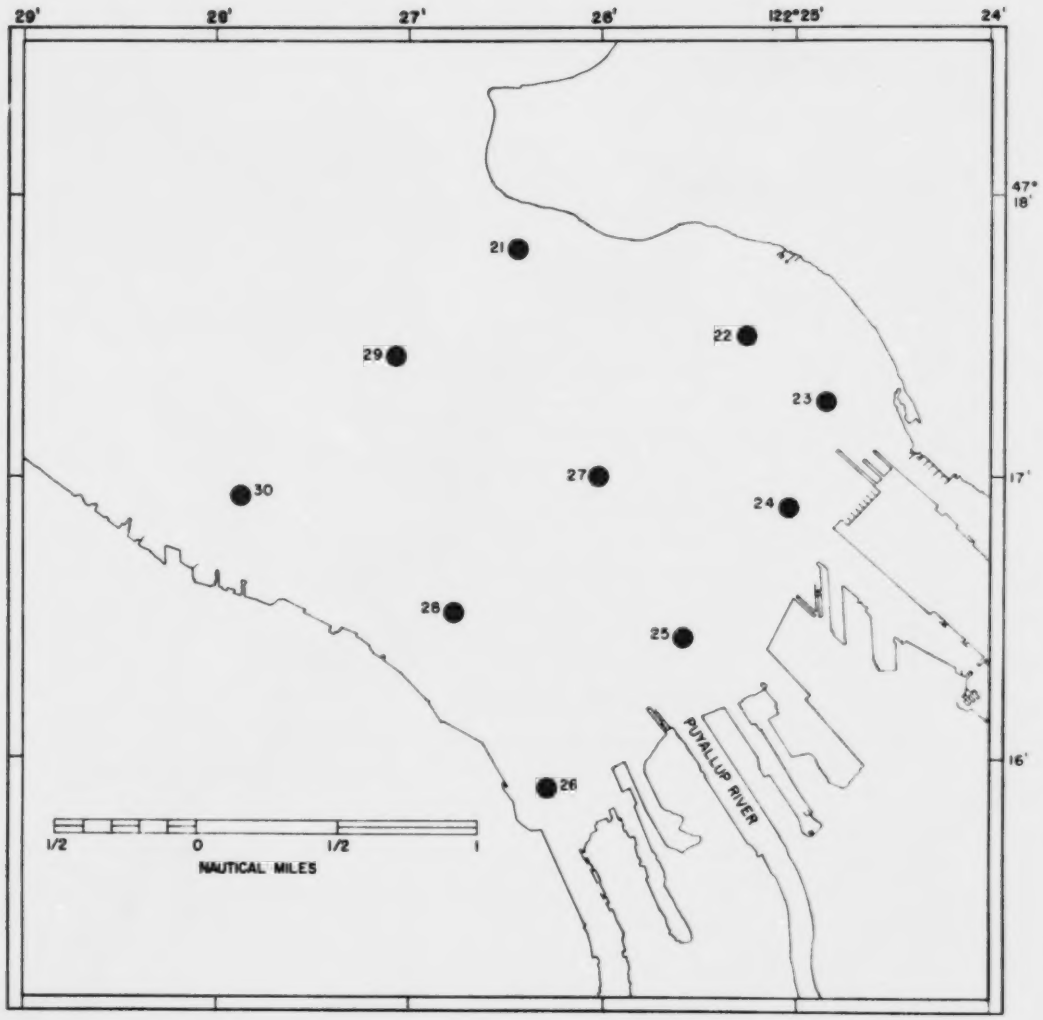


Figure 4. Station locations in Commencement Bay (SYOPS 3)

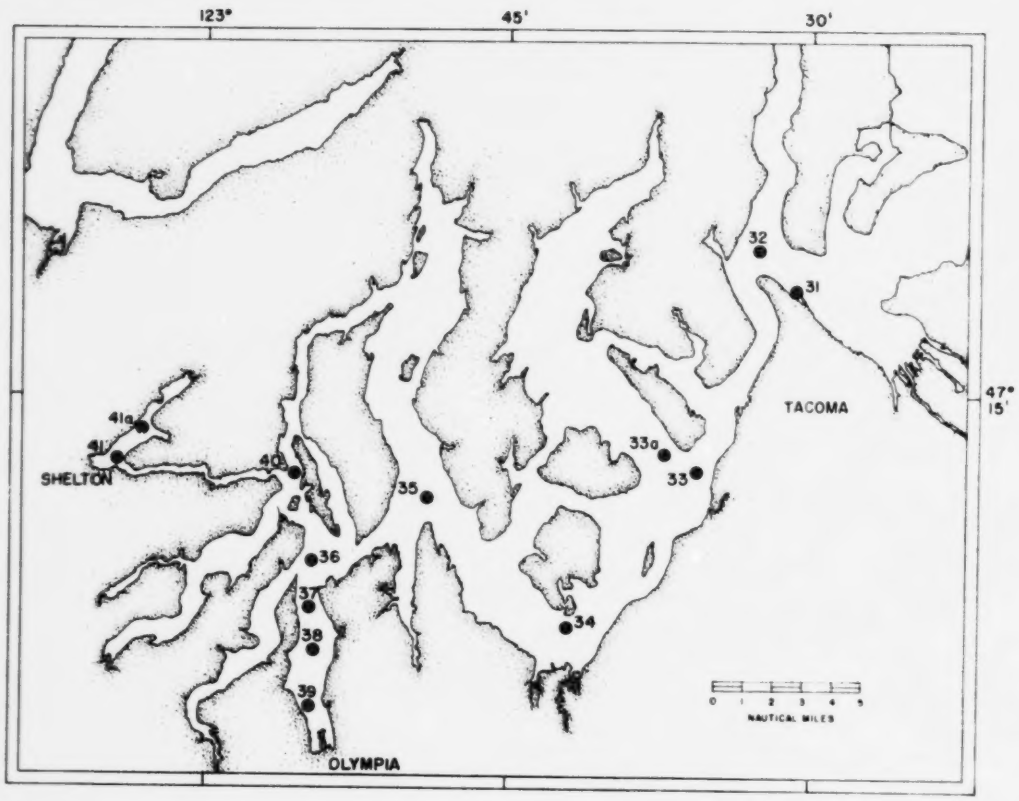


Figure 5. Station locations in Southern Puget Sound (SYOPS 3)

Preceding page blank

STATION LOG

SYOPS-1

STATION NUMBER	HYDRO	CHL	PN	ETS	PRO	ZOO
1	X	X	X	X	X	X
2	X	X	X	X	X	X
5	X	X	X	X	X	X
5-6		X	X	X	X	
6	X	X	X	X	X	X
6-7		X	X	X	X	
7	X	X	X	X	X	X
7-4		X	X	X	X	
10-11		X	X	X	X	
11	X	X	X	X	X	X
11-12		X	X	X	X	
12	X	X	X	X	X	
12-13		X	X	X	X	X
13	X	X	X	X	X	
14	X	X	X	X	X	X
14-15		X	X	X	X	
15	X	X	X	X	X	X
16	X	X	X	X	X	X
17	X	X	X	X	X	X
17-18		X	X	X	X	
18	X	X	X	X	X	X
19	X	X	X	X	X	X
19-20		X	X	X	X	X
20	X	X	X	X	X	

HYDRO--Hydrographic samples collected at routine depths. Variables measured are: temperature, salinity, and nutrients.

CHL--Chlorophyll-*a*

PN--Particulate nitrogen

ETS--Electron transport system enzymes

PRO--Protein

ZOO--Zooplankton for PCB analysis

STATION LOG

SYOPS 2

STATION NUMBER	SED
1	X
2	X
5	X
6	X
7	X
11	X
12	X
13	X
14	X
15	X
16	X
17	X
18	X
19	X
20	X

SED -- Sediment for PCB analysis

STATION LOG

SYOPS-3

STATION NUMBER	HYDRO	CHL	PN	ZOO	PHYTO	SED
21	X	X	X	X	X	X
22	X	X		X	X	X
23	X	X	X	X	X	X
24	X	X	X	X	X	X
25	X	X	X	X	X	X
26	X	X	X	X	X	X
27	X	X	X	X	X	X
28	X	X	X	X	X	X
29	X	X	X	X	X	X
30	X	X	X	X	X	X
33	X	X	X	X	X	X
34	X	X	X	X	X	X
35	X	X	X	X	X	X
36	X	X	X	X	X	X
37	X	X	X	X	X	X
38	X	X	X	X	X	X
39	X	X	X	X	X	X
40	X	X		X	X	X
41	X	X	X	X	X	X

HYDRO--Hydrographic samples collected at routine depths. Variables measured are: temperature, salinity, and nutrients.

CHL--Chlorophyll-a

PN--Particulate nitrogen

ZOO--Zooplankton for PCB analysis

PHYTO--Phytoplankton for PCB analysis

SED--Sediment for PCB analysis

STATION LOG

SYOPS 4

STATION NUMBER	HYDRO	ZOO	PHYTO	SED
3	X	X	X	X
5	X	X	X	X
8	X	X	X	X
10	X	X	X	X
11	X	X		
12	X		X	X
16	X		X	X

HYDRO -- Hydrographic samples collected at routine depths. Variables measured are: temperature, salinity, and nutrients.

ZOO -- Zooplankton for PCB analysis.

PHYTO -- Phytoplankton for PCB analysis.

SED -- Sediment samples for PCB analysis.

HYDROGRAPHIC, CHEMICAL AND BIOLOGICAL DATA (SYOPS 1, 3)

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS I									
STATION 01				LATITUDE 47° 41 00					STATION DATE 12/09/72
				LONGITUDE 122° 27 42					SECCHI 08.0 M
0	12.19			4.8774	0.4356				
3	11.82	29.465	22.36	4.7553	0.4247	2.06	38.43	21.13	0.383
6	12.13	29.503	22.33	4.6355	0.4140	2.05	38.48	20.84	0.403
15	11.79	29.576	22.45	4.3892	0.3920	2.38	40.07	20.43	
30	11.73	29.662	22.52	4.3892	0.3920	2.26	42.32	20.21	
CRUISE SYOPS I									
STATION 02				LATITUDE 47° 38 00					STATION DATE 12/09/72
				LONGITUDE 122° 28 00					SECCHI
0	12.78	29.563	22.26	4.7184	0.4214	2.33	40.69	18.74	
3	11.96	29.588	22.43	4.4765	0.3998	2.21	40.32	17.51	
6	11.79	29.596	22.46	4.3489	0.3884	2.04	38.50	20.89	0.241
15	11.70	29.640	22.50	4.2145	0.3764	1.84	27.30	15.38	0.243
30	11.64	29.681	22.56	4.2235	0.3772	2.30	41.37	20.66	
CRUISE SYOPS I									
STATION 05				LATITUDE 47° 35 47					STATION DATE 12/09/72
				LONGITUDE 122° 22 49					SECCHI 09.5 M
0	11.97	29.504	22.36	4.3086	0.3775	2.02	39.77	20.21	0.591
3	12.13	29.556	22.37	4.3489	0.3877	2.03	41.27	19.83	0.185
6	11.75	29.581	22.46	4.2436	0.3790	1.84	28.05	16.29	0.055
15	11.76	29.594	22.47	4.3411	0.3884	2.24	41.57	20.91	
30	11.72			4.2269	0.3848	2.29	40.57	20.30	

Preceding page blank

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS I STATION 06				LATITUDE 47° 35 11 LONGITUDE 122° 22 09					STATION DATE 12/09/72 SECCHI 10.5 M
0	13.03	28.584	21.45	4.5079	0.4026	2.50	45.84	23.27	1.283
3	12.44	29.290	22.11	4.3691	0.3902	2.45	42.64	19.85	0.429
6	11.35	29.534	22.41	4.3086	0.3848	2.13	39.13	22.84	0.109
15	11.76	29.568	22.45	4.2112	0.3761	2.36	42.52	20.76	
30	11.69	29.593	22.69	4.1496	0.3706	2.30	43.00	20.69	
CRUISE SYOPS I STATION 07				LATITUDE 47° 35 43 LONGITUDE 122° 22 09					STATION DATE 12/09/72 SECCHI 09.0 M
0	12.60	28.774	21.68	4.3489	0.3884				
3	12.19	29.304	22.16	4.3691	0.3902	2.19	41.11	20.38	0.462
6	12.00	29.481	22.34	4.3489	0.3884	2.21	37.31	18.24	
15	11.83	29.581	22.44	4.3814	0.3913				
30	11.72	29.623	22.50	4.9177	0.4392	2.13	29.47	20.39	0.640
CRUISE SYOPS I STATION 11				LATITUDE 47° 36 02 LONGITUDE 122° 21 30					STATION DATE 13/09/72 SECCHI 10.0 M
0	12.98	28.523	21.42	4.5236	0.4040	2.51	45.79	21.52	0.810
3	12.53	28.753	21.68	4.2884	0.3830	2.45	48.02	26.00	1.060
6	11.98	29.403	22.28	4.1865	0.3739	1.91	36.05	18.44	0.002
15	11.86	29.576		4.1138	0.3674	1.98	36.86	19.44	0.000
30	11.62	29.629	22.52	4.1138	0.3674	2.04	37.23	20.32	0.024

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L

CRUISE SYOPS I
STATION 12
LATITUDE 47° 35 12
LONGITUDE 122° 21 30
STATION DATE 13/09/72
SECCHI 07.5 M

0	13.59	27.238	20.31	4.2963	0.3837	3.52	61.08	27.28	3.359
3	12.38	28.862	21.79	4.1664	0.3721	2.70	49.63	24.96	1.786
6	12.12	29.356	22.22	4.2683	0.3812	2.08	41.57	20.47	0.432
15	12.00	29.532		4.1910	0.3743	2.15	42.45	21.84	0.269

CRUISE SYOPS I
STATION 13
LATITUDE 47° 34 33
LONGITUDE 122° 21 30
STATION DATE 13/09/72
SECCHI 06.0 M

0	13.18	27.329	20.51	4.2884	0.3830	2.31	30.05	13.05	1.225
3	12.21	28.707	21.70	4.2269	0.3775	2.50	49.07	21.80	0.961
6	11.90	29.309	22.22	4.1865	0.3739	2.01	30.56	15.38	0.695
15		29.575				1.42	20.59	10.17	0.000

CRUISE SYOPS I
STATION 14
LATITUDE 47° 35 38
LONGITUDE 122° 21 00
STATION DATE 13/09/72
SECCHI 08.0 M

0	12.51	28.167	21.23	4.3287	0.3866	2.46	47.16	19.75	1.665
3	11.98	29.228	22.15	4.2515	0.3797	2.20	42.20	20.89	0.460
6	11.85	29.452	22.34	4.2269	0.3775	2.34	45.90	23.55	0.136
15		29.563		4.2683	0.3812	2.21	44.86	23.34	0.056
30	11.67	29.613	22.50	4.1742	0.3728	1.99	42.12	20.91	0.000

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS I STATION 15				LATITUDE 47° 36 32 LONGITUDE 122° 21 00					STATION DATE 13/09/72 SECCHI 09.0 M
0	12.47	28.449	21.46	4.3489	0.3884	2.58	51.09	23.84	1.117
3	12.04	29.127	22.06	4.2313	0.3779	2.06	45.02	20.61	0.387
6	11.79	29.491	22.38	4.1787	0.3732	2.23	45.69	23.41	0.063
15	11.71	29.576	22.46	4.1048	0.3666	1.99	41.00	20.16	0.000
30	11.64	29.597	22.49	3.5360	0.3158	2.24	44.99	24.00	0.000
CRUISE SYOPS I STATION 16				LATITUDE 47° 36 16 LONGITUDE 122° 20 32					STATION DATE 14/09/72 SECCHI 11.0 M
0	12.39	28.453	21.47	4.3590	0.3983	2.60	45.68	21.68	1.680
3	12.00	29.087	22.03	4.2683	0.3812	2.29	41.97	22.47	0.569
6	11.84	29.444	22.34	4.2269	0.3775	2.10	40.38	21.05	0.146
15	11.73	29.586	22.47	4.1865	0.3739	2.03	39.47	21.29	0.023
30	11.65	29.623	22.51	4.0690	0.3634	1.99	40.23	19.09	0.025
CRUISE SYOPS I STATION 17				LATITUDE 47° 35 57 LONGITUDE 122° 20 24					STATION DATE 14/09/72 SECCHI 08.5 M
0	12.55	28.554	21.52	4.3086	0.3848	2.59	37.71	22.86	1.078
3	12.35	29.039	21.91	4.2190	0.3768	1.87	30.25	15.08	0.757
6	12.40	29.381	22.26	4.2638	0.3808	1.87	35.85	20.13	0.161
15	11.73			4.1787	0.3732	1.82	25.61	16.15	0.038
30	11.64	29.639	22.52	4.0791	0.3643	2.24	42.58	23.48	0.015

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS 1 STATION 18				LATITUDE 47° 35 25 LONGITUDE 122° 21 00					STATION DATE 14/09/72 SECCHI 07.0 M
0	13.46	26.892	20.07	3.9917	0.3565	3.14	44.38	23.02	2.660
3	12.08	29.193	22.10	4.1216	0.3681	2.14	39.27	19.76	0.476
6	11.92	29.525	22.38	4.2683	0.3812	1.56	28.45	12.95	0.000
15	11.67	29.605	22.49	4.1910	0.3743	2.14	38.00	22.65	0.008
30	11.54	29.665	22.56	4.6333	0.4138	2.15	44.08	23.28	0.000
CRUISE SYOPS 1 STATION 19				LATITUDE 47° 25 30 LONGITUDE 122° 20 36					STATION DATE 14/09/72 SECCHI 05.5 M
0	14.20	26.370	19.53			3.71	36.65	27.73	3.481
3	12.57	28.342	21.35	4.2683	0.3812	2.81	33.27	24.84	1.753
6	12.06	29.342	22.22	4.2470	0.3793	1.94	29.90	15.31	0.437
15	11.77	29.580	22.45	4.2145	0.3764	2.20	39.70	23.40	0.139
CRUISE SYOPS 1 STATION 20				LATITUDE 47° 34 33 LONGITUDE 122° 20 36					STATION DATE 14/09/72 SECCHI 03.5 M
0	14.19	25.454	18.83	4.3691	0.3902	4.35	50.88	28.75	5.061
3	12.26	28.893	21.84	4.1138	0.3674	2.55	46.60	21.86	1.651
6	11.85	27.614	20.92	3.9424	0.3521	2.19	30.33	19.92	1.670
12	11.73	29.561	22.45	3.9368	0.3516	2.07	38.86	19.76	1.374

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS 3				LATITUDE 47° 17 48					STATION DATE 06/02/73
STATION 21				LONGITUDE 122° 26 36					SECCHI 05.5 M
0	07.26	28.418	22.24	5.894	0.5264	2.359	61.56	22.17	0.2272
5	07.43	29.098	22.75	5.658	0.5053	1.832	47.03	15.53	0.0460
10	07.50	29.220	22.84	5.856	0.4989	2.153	60.73	22.94	0.0802
15	07.45	29.310	22.91	5.650	0.5046	1.898	47.39	16.28	0.0392
30	07.47	29.348	22.94	5.654	0.5050	2.424	56.29	25.90	0.0000
CRUISE SYOPS 3				LATITUDE 47° 17 30					STATION DATE 06/02/73
STATION 22				LONGITUDE 122° 25 36					SECCHI 05.0 M
0	07.34	28.381	22.20	5.854	0.5228	2.209	48.88	19.35	0.2924
5	07.38	29.051	22.72	5.702	0.5092	1.350	38.89	14.17	0.3192
10	07.50	29.303	22.90	5.662	0.5057	2.382	59.39	20.94	0.3629
15	07.52	29.350	22.94	5.606	0.5007	1.678	24.53	07.36	0.1053
CRUISE SYOPS 3				LATITUDE 47° 17 06					STATION DATE 06/02/73
STATION 23				LONGITUDE 122° 24 48					SECCHI 02.0 M
0	06.89	23.912	18.75	6.034	0.5389	2.025	62.02	25.49	0.0264
5	07.44	28.528	22.30			1.859	35.61	14.96	0.4582
10	07.52	29.221	22.82	6.197	0.5535	2.278	53.98	25.18	0.0389
15	07.52	29.322	22.91	5.582	0.4985	2.010	45.47	19.65	0.1916

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS 3									
STATION 24				LATITUDE 47° 16 54					STATION DATE 05/02/73
				LONGITUDE 122° 25 06					SECCHI
0	07.02	26.280	20.59	5.846	0.5221	1.448	23.63	12.28	0.2468
5	07.48	28.811	22.52	5.506	0.4917	2.264	65.52	23.24	0.1376
10	07.50	29.072	22.72	5.518	0.4928	2.417	51.66	20.62	0.0177
15	07.49	29.172	22.80	5.502	0.4914	2.256	58.32	24.41	0.0245
30	07.51	29.279	22.88	5.458	0.4875	2.314	63.89	18.48	1.0931
CRUISE SYOPS 3									
STATION 25				LATITUDE 47° 16 24					STATION DATE 05/02/73
				LONGITUDE 122° 25 18					SECCHI 02.0 M
0	07.27	26.566	20.79	5.662	0.5057	1.961	37.33	16.12	1.0266
5	07.52	29.253	22.86			2.095	46.18	18.13	0.1893
10	07.54	29.375	22.95	5.466	0.4882	2.452	57.18	22.49	0.2877
15	07.55	29.415	22.98	5.426	0.4846	2.433	63.16	22.06	0.2986
30	07.57	29.463	23.02			2.250	62.41	19.30	0.0636
CRUISE SYOPS 3									
STATION 26				LATITUDE 47° 15 54					STATION DATE 05/02/73
				LONGITUDE 122° 26 18					SECCHI 02.0 M
0	06.54	18.417	14.48	6.005	0.5363	1.518	46.99	15.99	6.3021
5	07.50	28.955	22.63	5.402	0.4825	2.098	42.93	17.51	0.1683
10	07.55	29.226	22.83	5.418	0.4839	2.220	49.40	21.16	0.3181
15	07.54	29.345	22.93	5.486	0.4900	2.190	32.43	21.93	0.2415
30	07.55	29.423	22.99	5.434	0.4853	1.801	40.78	09.62	0.1620

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS 3				LATITUDE 47° 17 00					STATION DATE 05/02/73
STATION 27				LONGITUDE 122° 26 00					SECCHI
0	06.68	25.857	20.30	5.858	0.5232	1.405	59.14	11.20	0.0629
5	07.44	29.061	22.72	5.566	0.4971	1.818	41.11	13.03	0.0052
10	07.52	29.047	22.70	5.490	0.4903	2.319	50.16	20.68	0.0577
15	07.50	29.268	22.87	5.494	0.4907	2.290	52.74	20.93	0.0603
30	07.51	29.338	22.93	5.478	0.4892	1.520	34.46	11.34	0.1457
CRUISE SYOPS 3				LATITUDE 47° 16 36					STATION DATE 06/02/73
STATION 28				LONGITUDE 122° 26 42					SECCHI 02.0 M
0	06.38	25.480	20.04	6.317	0.5642	1.734	43.62	18.15	0.0000
5	07.36	28.909	22.61	5.750	0.5135	1.766	43.59	12.59	0.0185
10	07.42	29.230	22.85	5.654	0.5050	2.221	65.77	23.67	0.6490
15	07.46	29.377	22.96	5.646	0.5042	2.511	37.86	29.27	0.0000
30	07.45	29.379	22.97	5.686	0.5078	2.443	48.66	22.54	0.7318
CRUISE SYOPS 3				LATITUDE 47° 17 24					STATION DATE: 06/02/73
STATION 29				LONGITUDE 122° 27 03					SECCHI 03.5 M
0	06.87	27.024	21.20	6.061	0.5413	2.333	69.33	23.80	0.1689
5	07.22	28.936	22.65	5.714	0.5103	1.052	35.38	13.90	
10	07.50	29.197	22.82	5.638	0.5035	2.264	45.93	19.13	0.0236
15	07.32	29.261	22.89	5.662	0.5057	2.487	47.91	27.51	0.0706
30	07.46	29.375	22.96	5.574	0.4978	2.265	65.52	22.76	0.1422

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS 3				LATITUDE 47° 17 00					STATION DATE 06/02/73
STATION 30				LONGITUDE 122° 27 54					SECCHI
0	06.15	22.049	17.37	6.305	0.5631	1.784	49.84	16.62	0.0761
5	07.32	29.187	22.83	5.605	0.5006	1.670	22.74	08.29	0.2109
10	07.42	29.326	22.93	5.542	0.4950	2.510	52.05	27.94	0.0000
15	07.38	29.329	22.94	5.562	0.4967	2.512	34.35	27.58	0.0060
30	07.39	29.365	22.96	5.570	0.4975	2.605	59.77	23.02	0.2624
CRUISE SYOPS 3				LATITUDE 47° 12 18					STATION DATE 08/02/73
STATION 33				LONGITUDE 122° 35 42					SECCHI 05.0 M
0	06.91	28.285	22.18	5.953	0.5317	1.642	30.34	14.44	0.2656
5	07.11	28.896	22.63	5.801	0.5181	1.581	35.79	11.60	1.0893
10	07.09	29.034	22.74	5.789	0.5170	1.777	21.76	14.88	0.1340
15	07.22	29.093	22.77	5.717	0.5106	1.988	63.94	14.19	0.2289
30	07.22	29.113	22.79			1.524	42.98	17.45	
CRUISE SYOPS 3				LATITUDE 47° 07 00					STATION DATE 08/02/73
STATION 34				LONGITUDE 122° 42 06					SECCHI 05.0 M
0	06.95	28.439	22.29	5.857	0.5231	2.126	38.87	23.04	0.1019
5	07.09	28.753	22.52	5.757	0.5142	2.542	65.52	23.14	0.2331
10	07.14	28.902	22.63	5.729	0.5117	1.586	104.81	20.62	0.1522
15	07.13	28.984	22.70	5.753	0.5138	2.489	71.63	20.49	0.1418
30	07.20	29.038	22.73	5.741	0.5127	2.453	34.63	26.89	0.0000

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS 3				LATITUDE 47° 11 30					STATION DATE 07/02/73
STATION 35				LONGITUDE 122° 49 00					SECCHI
0	06.72	28.487	22.36	5.961	0.5324	2.609	77.38	22.36	0.0905
5	06.75	28.493	22.36	6.037	0.5392	2.127	39.80	22.49	0.2116
10	06.80	28.556	22.40	5.905	0.5274	2.464	39.06	25.81	0.0821
15	06.89	28.604	22.43	5.845	0.5220	1.685	36.82	16.13	1.9264
30	06.92	28.641	22.46	5.821	0.5199	2.489	70.44	24.46	0.1510
CRUISE SYOPS 3				LATITUDE 47° 09 18					STATION DATE 07/02/73
STATION 36				LONGITUDE 122° 54 12					SECCHI 04.1 M
0	06.59	28.162	22.12	5.997	0.5356	2.283	59.77	19.47	0.2842
5	06.60	28.181	22.13			2.768	83.48	22.63	0.2783
10	06.59	28.175	22.13	5.953	0.5317	2.248	59.63	20.20	0.4041
15	06.58	28.230	22.17	5.981	0.5342	2.488	61.23	23.31	0.4007
30	06.61	28.283	22.12	5.929	0.5295	2.417	61.99	22.17	0.1187
CRUISE SYOPS 3				LATITUDE 47° 07 36					STATION DATE 07/02/73
STATION 37				LONGITUDE 122° 54 30					SECCHI 04.1 M
0	06.67	28.001	21.98	5.854	0.5228	2.513	37.73	26.28	0.6700
5	06.53	28.058	22.05	5.874	0.5246	2.268	64.16	24.84	0.0631
10	06.50	28.129	22.10	6.048	0.5415	2.548	41.89	29.41	0.1115

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L

CRUISE SYOPS 3
STATION 38
LATITUDE 47° 06 12
LONGITUDE 122° 54 24
STATION DATE 07/02/73
SECCHI 04.2 M

0	06.40	27.843	21.89	6.127	0.5472	2.291	36.83	22.14	0.8098
5	06.58	28.061	22.04	5.870	0.5242	2.172	61.72	17.00	0.5050
10	06.69	28.149	22.10	5.846	0.5221	2.437	53.26		0.1103

CRUISE SYOPS 3
STATION 39
LATITUDE 47° 04 18
LONGITUDE 122° 54 24
STATION DATE 07/02/73
SECCHI 02.0 M

0	05.39	25.580	20.22	6.245	0.5577	2.013	69.76	15.10	0.0947
5	06.25	27.319	21.50	6.249	0.5581	2.409	83.49	20.06	0.9942
10	06.51	27.643	21.72	5.870	0.5242	2.488	61.23	23.31	0.4007

CRUISE SYOPS 3
STATION 40
LATITUDE 47° 12 12
LONGITUDE 122° 55 42
STATION DATE 07/02/73
SECCHI

0	06.24	27.170	21.38	6.165	0.5506	1.357	68.30	12.08	0.1633
5	06.26	27.238	21.43	6.177	0.5517	2.442	75.76	20.10	0.5108

CRUISE SYOPS 3
STATION 41
LATITUDE 47° 12 42
LONGITUDE 123° 04 24
STATION DATE 07/02/73
SECCHI 01.5 M

0	05.59	23.682	18.71	6.289	0.5617	2.113	61.70	20.70	0.6931
5	05.54	23.920	18.90	6.265	0.5595	2.173	81.21	18.91	0.6387
10	05.74	25.048	19.77	6.087	0.5436	2.173	42.57	20.85	0.5842
15	05.78	25.329	19.98	6.099	0.5447	1.795	51.92	15.21	1.0944

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS 4 STATION 03				LATITUDE 47° 37 36 LONGITUDE 122° 22 49				STATION DATE 06/06/73 SECCHI 08.5 M	
0	11.80	28.328	21.48	6.381	0.5699	3.107	27.00	10.66	3.352
5		29.265		6.414	0.5728	2.751	26.16	10.37	3.270
10	11.74	29.503	22.40	6.304	0.5630	2.633	52.05	19.03	10.900
15	10.42	29.503	22.63	6.249	0.5581	2.462	27.91	12.50	3.332
30	09.88	29.782	22.93	6.072	0.5423	2.748	27.62	09.96	3.479
CRUISE SYOPS 4 STATION 05				LATITUDE 47° 35 47 LONGITUDE 122° 22 49				STATION DATE 06/06/73 SECCHI 09.0 M	
0	10.24	29.602	22.73	6.266	0.5596	2.179	32.23	12.98	4.688
5	10.33	29.625	22.73			2.115	34.71	11.77	2.901
10	10.28	29.681	22.79	6.229	0.5563	2.335	21.35	07.06	3.045
15	10.10	29.735	22.86	6.126	0.5471	2.378	36.01	12.83	4.996
30	09.94	29.792	22.93	6.052	0.5405	2.134	27.78	10.73	3.704
CRUISE SYOPS 4 STATION 08				LATITUDE 47° 36 36 LONGITUDE 122° 22 09				STATION DATE 06/06/73 SECCHI 09.0 M	
0	11.16	28.523	21.74	6.282	0.5610	2.835	22.38	07.44	3.011
5		29.609		6.348	0.5669	2.351	25.52	12.18	3.398
10	10.00	29.639	22.80	6.299	0.5626	2.551	27.06	13.51	3.409
15	09.98	29.674	22.83	6.249	0.5581	2.582	27.25	12.14	3.284
30	09.86	29.780	22.93	6.056	0.5409	2.516	27.26	12.85	3.243

STATION REPORT

Depth M	TEMP DEG. C	SAL 0/00	SIGMAT	O_2 ML/L	O_2 MGAT/L	PO_4 µGAT/L	SIO_4 µGAT/L	NO_3 µGAT/L	NH_4 µGAT/L
CRUISE SYOPS 4 STATION 10			LATITUDE 47° 36 51 LONGITUDE 122° 21 30					STATION DATE 06/06/73 SECCHI 05.2 M	
0	11.54	28.161	21.40			3.140	26.31	10.19	3.295
5	10.34	29.386	22.55			2.048	24.98	11.01	3.210
10	09.96	29.660	22.82			2.603	29.37	10.79	
25	09.73	29.766	22.94	6.080	0.5430	2.288	26.72	10.67	3.217
CRUISE SYOPS 4 STATION 11			LATITUDE 47° 36 02 LONGITUDE 122° 21 30					STATION DATE 06/06/73 SECCHI	
0	10.64	28.747	22.00	6.183	0.5522	2.916	27.07	13.74	3.606
5	10.54	29.169	22.35	6.253	0.5585	2.708	26.39	10.59	3.423
10	10.47	29.350	22.50	6.336	0.5659	2.686	26.14	10.84	3.401
15	10.06	29.632	22.78	6.274	0.5603	2.438	23.74	09.64	3.080
30	09.84	29.768	22.93	6.093	0.5492	2.666	25.18	11.22	3.263
CRUISE SYOPS 4 STATION 12			LATITUDE 47° 35 12 LONGITUDE 122° 21 30					STATION DATE 06/06/73 SECCHI 03.0 M	
0	11.62	25.644	19.44	5.821	0.5199		32.82	14.61	4.692
5	10.13	29.434	22.62	6.109	0.5456	2.744	33.87	11.78	4.689
10	09.90	29.710	22.87	6.138	0.5482	2.324	26.16	11.13	3.243
CRUISE SYOPS 4 STATION 16			LATITUDE 47° 36 16 LONGITUDE 122° 20 32					STATION DATE 06/06/73 SECCHI 06.5 M	
0	11.56	28.460	21.63	6.282	0.5610	2.714	26.35	10.29	3.246
5	10.33	29.394	22.56	6.146	0.5489	2.389	26.24	12.15	3.181
10	09.95	29.655	22.82	6.138	0.5482	2.319	27.60	12.75	3.342
15	09.91	29.743	22.89	6.134	0.5478	2.492	27.92	10.86	3.895
30	09.93	29.770	22.91	6.068	0.5419	2.433	27.39	11.89	3.295

Preceding page blank

PRODUCTIVITY DATA

(SYOPS 1, 3)

PRODUCTIVITY UNITS

Nutrient concentrations	µg-at/liter
Chlorophyll-*a* concentration	µg/liter
Particulate carbon (PC)	mg^{C}/liter
Particulate nitrogen concentration (PN)	µg-atN/liter
Electron transport activity (ETS)	µℓ O_2/ℓ/hr

PRODUCTIVITY REPORT

CRUISE SYOPS I
STATION 01

LATITUDE 47° 41 00
LONGITUDE 122° 27 42

STATION DATE 12/09/72
SECCHI 08.0M

DEPTH (M)	CHL-A	PN	PC	PETS	PROTEIN ($x10^{-3}$)	ØETS ($x10^{-3}$)	PROTEIN	ØETS(1%) ($x10^{-3}$)	PROTEIN	ZETS ($x10^{-2}$)	PROTEIN
0	1.9069		0.4742	1.236	177.75	16.231	4.079	10.901	1.943	0.681	1.370
3	1.8686	2.80	0.4239	1.226	189.00						
6	1.3086	2.14	0.4479	0.637	96.60						
15			0.3814	0.343	117.70						
30	0.7134	1.85	0.2862	0.368	167.08						

CRUISE SYOPS I
STATION 02

LATITUDE 47° 38 00
LONGITUDE 122° 28 00

STATION DATE 12/09/72
SECCHI

0	0.6948	2.05		0.790	160.00	20.943	2.823			0.791	3.138
3	1.6580	2.28	0.3287	0.962	184.00						
6	1.3869	1.65	0.2657	0.858	74.00						
30	0.9926	2.17	0.2140	0.441	86.03						

CRUISE SYOPS I
STATION 05

LATITUDE 47° 35 47
LONGITUDE 122° 22 49

STATION DATE 12/09/72
SECCHI 09.5M

0	0.6665	1.19	0.3643	0.242	112.00	5.463	1.648	3.798	1.030	0.086	0.423
3	0.6978	1.22	0.3195	0.224	64.50						
6	0.5161	1.33	0.2987	0.212	30.75						
15	0.5886	0.92	0.2758	0.162	49.45						
30	0.4273	0.70	0.2164	0.162	67.85						

PRODUCTIVITY REPORT

CRUISE SYOPS I
STATION 06
LATITUDE 47° 35 11
LONGITUDE 122° 22 09
STATION DATE 12/09/72
SECCHI 10.5M

DEPTH (M)	*CHL-A*	*PN*	*PC*	*PETS*	*PROTEIN* ($x10^{-3}$)	*ΦETS* ($x10^{-3}$)	*PROTEIN*	*ΦETS(1%)* ($x10^{-3}$)	*PROTEIN*	*ZETS* ($x10^{-2}$)	*PROTEIN*
0	0.5812	1.54	0.2932	0.261	114.00	17.645	2.090	6.693	1.926	0.018	0.137
3	0.5898	1.37	0.3551	0.341	90.00						
6	0.6667	1.10	0.2121	0.579	138.00						
15	0.2614	1.18	0.2989	0.139	58.00						
30	0.3846	0.70	0.2416	0.146	57.00						

CRUISE SYOPS I
STATION 07
LATITUDE 47° 35 43
LONGITUDE 122° 22 09
STATION DATE 12/09/72
SECCHI 09.0M

0	0.7897	1.66		0.211	642.60	8.027	3.512	11.261	2.638	0.320	1.187
3	0.7854	1.62	0.1811	0.267	280.85						
6	0.6595	1.33	0.5325	0.541	30.00						
15	0.5352	1.33	0.3746	0.217	75.85						
30	0.5093	1.28	0.2 31	0.142	82.00						

CRUISE SYOPS I
STATION 11
LATITUDE 47° 36 02
LONGITUDE 122° 21 30
STATION DATE 13/09/72
SECCHI 10.0M

0	0.5540	1.44		0.496	150.15	7.185	5.015	4.893	3.196	0.135	0.702
3	0.5664	1.37	0.1682	0.283	118.00						
6	0.6896	0.82	0.1371	0.268	106.00						
15	0.3121	0.98	0.1633	0.241	186.20						
30	0.4765	1.33	0.1213	0.145	208.65						

PRODUCTIVITY REPORT

CRUISE SYOPS I
STATION 12

LATITUDE 47° 35 12
LONGITUDE 122° 21 30

STATION DATE 13/09/72
SECCHI 07.5M

DEPTH (M)	CHL-A	PN	PC	PETS	PROTEIN ($x10^{-3}$)	ΦETS ($x10^{-3}$)	PROTEIN	ΦETS(1%) ($x10^{-3}$)	PROTEIN	ZETS ($x10^{-2}$)	PROTEIN
										0.267	1.601
0	0.6492	1.46		0.350	110.00	3.282	0.780				
3	0.8851	1.63	0.1914	0.295	72.20						
6	0.7856	0.90	0.3090	0.309	68.00						
10	0.7242	1.20	0.2004	0.395	80.00						

CRUISE SYOPS I
STATION 13

LATITUDE 47° 34 33
LONGITUDE 122° 21 30

STATION DATE 13/09/72
SECCHI 06.0M

0	0.8937	2.00		0.694	79.95	5.158	0.716	5.158	0.716	0.050	0.143
3	0.7093	1.35	0.1268	1.034	86.00						
6	1.5464	1.02	0.1714	0.230	71.40						
10	0.5585	1.02	0.2786	0.104	44.65						

CRUISE SYOPS I
STATION 14

LATITUDE 47° 35 38
LONGITUDE 122° 21 00

STATION DATE 13/09/72
SECCHI 08.0M

0		1.49		0.410	136.80	9.115	2.169	3.460	1.086	0.066	0.497
3	0.6504	1.28	0.1650	0.261	85.50						
6	0.4969	1.39	0.1211	0.694	56.70						
15	0.3039	1.60	0.3375	0.184	63.38						
30	0.2083	1.02	0.1191	0.179	81.00						

PRODUCTIVITY REPORT

CRUISE SYOPS I
STATION 15

LATITUDE 47° 36 32
LONGITUDE 122° 21 00

STATION DATE 13/09/72
SECCHI 09.0M

DEPTH (M)	*CHL-A*	*PN*	*PC*	*PETS*	*PROTEIN* ($x10^{-3}$)	*ΦETS* ($x10^{-3}$)	*PROTEIN*	*ΦETS(1%)* ($x10^{-3}$)	*PROTEIN*	*ZETS* ($x10^{-2}$)	*PROTEIN*
0	0.7924	1.89		0.262	89.30	5.263	1.647	4.240	1.092	0.054	0.163
3	0.4162	0.95	0.1914	0.199	76.00						
6	0.4695	0.91	0.1607	0.126	42.00						
15	0.4122	1.19	0.2357	0.204	57.00						
30	0.3274	1.18	0.0853	0.143	46.55						

CRUISE SYOPS I
STATION 16

LATITUDE 47° 36 16
LONGITUDE 122° 20 32

STATION DATE 14/09/72
SECCHI 11.0M

0	0.7854	1.35		0.223	44.65	4.308	1.154	3.507	0.845	0.069	0.317
3	0.6238	0.86	0.1543	0.188	43.88						
6	0.5585	0.98	0.1054	0.134	32.80						
15	0.3352	0.67	0.0975	0.123	29.45						
30	0.4190	0.82	0.0830	0.151	54.00						

CRUISE SYOPS I
STATION 17

LATITUDE 47° 35 57
LONGITUDE 122° 20 24

STATION DATE 14/09/72
SECCHI 08.5M

0	0.8317	1.43		0.329	93.00	8.554	1.941	4.491	1.128	0.043	0.196
3	0.9520	1.09	0.1601	0.044	76.00						
6	0.9483	0.90	0.1189	0.469	68.00						
15	0.5120	0.63	0.2432	0.154	69.70						
30	0.3570	0.29	0.0613	0.436	57.40						

PRODUCTIVITY REPORT

CRUISE SYOPS I
STATION 18

LATITUDE 47° 35 25
LONGITUDE 122° 21 00

STATION DATE 14/09/72
SECCHI 07.0M

DEPTH (M)	*CHL-A*	*PN*	*PC*	*PETS*	*PROTEIN* ($x10^{-3}$)	*ϕETS* ($x10^{-3}$)	*PROTEIN*	*ϕETS(1%)* ($x10^{-3}$)	*PROTEIN*	*ZETS* ($x10^{-2}$)	*PROTEIN*
0	0.8894	1.22		0.714	99.00	6.293	2.294	3.746	1.303	0.073	0.414
3	1.1595	0.83	0.1584	0.278	161.00						
6	1.3307	1.64	0.1719	0.183	81.00						
15	0.5655	1.04	0.1521	0.167	72.45						
30	0.6382	0.68	0.1429	0.132	41.00						

CRUISE SYOPS I
STATION 19

LATITUDE 47° 25 30
LONGITUDE 122° 20 36

STATION DATE 14/09/72
SECCHI 05.5M

0	0.9469	1.49		0.619	105.00	4.380	0.846	4.380	0.846	0.035	0.090
3	0.9904	1.46	0.2293	0.413	87.75						
6	0.9327	1.30	0.1521	0.430	90.00						
10		1.09	0.1459	0.355	55.00						

CRUISE SYOPS I
STATION 20

LATITUDE 47° 34 33
LONGITUDE 122° 20 36

STATION DATE 14/09/72
SECCHI 03.5M

0	0.9821	2.77		1.401	204.00	5.803	0.992	3.616	0.780	0.140	1.049
3	1.2028		0.2368	0.613	93.60						
6	0.7295	0.63	0.1504	0.378	69.00						
10	0.9254	0.78	0.2100	0.272	82.00						

PRODUCTIVITY REPORT

CRUISE SYOPS 3
STATION 21

LATITUDE 47° 17 48
LONGITUDE 122° 26 36

STATION DATE 06/02/73
SECCHI 05.5 M

DEPTH (M)	*CHL-A*	*PN*
0	1.586	2.05
5		
10	0.687	1.22
15		
30	0.945	

CRUISE SYOPS 3
STATION 22

LATITUDE 47° 17 30
LONGITUDE 122° 25 36

STATION DATE 06/02/73
SECCHI 05.0 M

0	0.858	
5		
10	0.805	
15		

CRUISE SYOPS 3
STATION 23

LATITUDE 47° 17 06
LONGITUDE 122° 24 48

STATION DATE 06/02/73
SECCHI 02.0 M

0	3.350	7.91
5		
10		
15	0.599	2.26

PRODUCTIVITY REPORT

CRUISE SYOPS 3 — LATITUDE 47° 16 54 — STATION DATE 05/02/73
STATION 24 — LONGITUDE 122° 25 06 — SECCHI

DEPTH (M)	*CHL-A*	*PN*
0	1.687	2.44
5		
10	0.818	1.00
15		
30	0.967	0.81

CRUISE SYOPS 3 — LATITUDE 47° 16 24 — STATION DATE 05/02/73
STATION 25 — LONGITUDE 122° 25 18 — SECCHI 02.0 M

0	1.543	1.55
5		
10	1.219	
15		
30	1.373	

CRUISE SYOPS 3 — LATITUDE 47° 15 54 — STATION DATE 05/02/73
STATION 26 — LONGITUDE 122° 26 18 — SECCHI 02.0 M

0	2.635	3.60
5		
10	0.967	1.40
15		
30		

PRODUCTIVITY REPORT

CRUISE SYOPS 3
STATION 27

LATITUDE 47° 17 00
LONGITUDE 122° 26 00

STATION DATE 05/02/73
SECCHI

DEPTH (M)	*CHL-A*	*PN*
0	1.818	1.98
5		
10	0.421	2.46
15		
30	0.315	0.81

CRUISE SYOPS 3
STATION 28

LATITUDE 47° 16 36
LONGITUDE 122° 26 42

STATION DATE 06/02/73
SECCHI 02.0 M

0	1.352	7.09
5		
10	1.411	0.87
15		
30	0.842	

CRUISE SYOPS 3
STATION 29

LATITUDE 47° 17 24
LONGITUDE 122° 27 03

STATION DATE 06/02/73
SECCHI 03.5 M

0	1.013	2.43
5		
10	1.070	1.03
15		
30	0.692	

PRODUCTIVITY REPORT

CRUISE SYOPS 3
STATION 30
LATITUDE 47° 17 00
LONGITUDE 122° 27 54
STATION DATE 06/02/73
SECCHI

DEPTH (M)	*CHL-A*	*PN*
0	0.938	7.39
5		
10	0.938	0.73
15		
30	0.589	0.52

CRUISE SYOPS 3
STATION 33
LATITUDE 47° 12 18
LONGITUDE 122° 35 42
STATION DATE 08/02/73
SECCHI 05.0 M

0	1.152	0.82
5		
10	0.945	1.19
15		
30	0.767	0.70

CRUISE SYOPS 3
STATION 34
LATITUDE 47° 07 00
LONGITUDE 122° 42 06
STATION DATE 08/02/73
SECCHI 05.0 M

0	0.867	
5		
10	0.686	0.98
15		
30	0.798	0.79

PRODUCTIVITY REPORT

CRUISE SYOPS 3
STATION 35

LATITUDE 47° 17 00
LONGITUDE 122° 49 00

STATION DATE 07/02/73
SECCHI

DEPTH (M)	*CHL-A*	*PN*
0	0.858	
5		
10	0.921	
15		
30	0.937	0.62

CRUISE SYOPS 3
STATION 36

LATITUDE 47° 09 18
LONGITUDE 122° 54 12

STATION DATE 07/02/73
SECCHI 04.1 M

0	0.759	0.95
5		
10	1.856	1.62
15		
30	1.263	1.48

CRUISE SYOPS 3
STATION 37

LATITUDE 47° 07 36
LONGITUDE 122° 54 30

STATION DATE 07/02/73
SECCHI 04.1 M

0	1.560	1.95
5		
10	2.242	1.23

PRODUCTIVITY REPORT

CRUISE SYOPS 3
STATION 38

LATITUDE 47° 06 12
LONGITUDE 122° 54 24

STATION DATE 07/02/73
SECCHI 04.2 M

DEPTH (M)	*CHL-A*	*PN*
0	2.036	
5		
10	1.323	1.24

CRUISE SYOPS 3
STATION 39

LATITUDE 47° 04 18
LONGITUDE 122° 54 24

STATION DATE 07/02/73
SECCHI 02.0 M

0	2.230	4.93
5		
10	1.439	

CRUISE SYOPS 3
STATION 40

LATITUDE 47° 12 12
LONGITUDE 122° 55 42

STATION DATE 07/02/73
SECCHI

0	0.990	
5		

CRUISE SYOPS 3
STATION 41

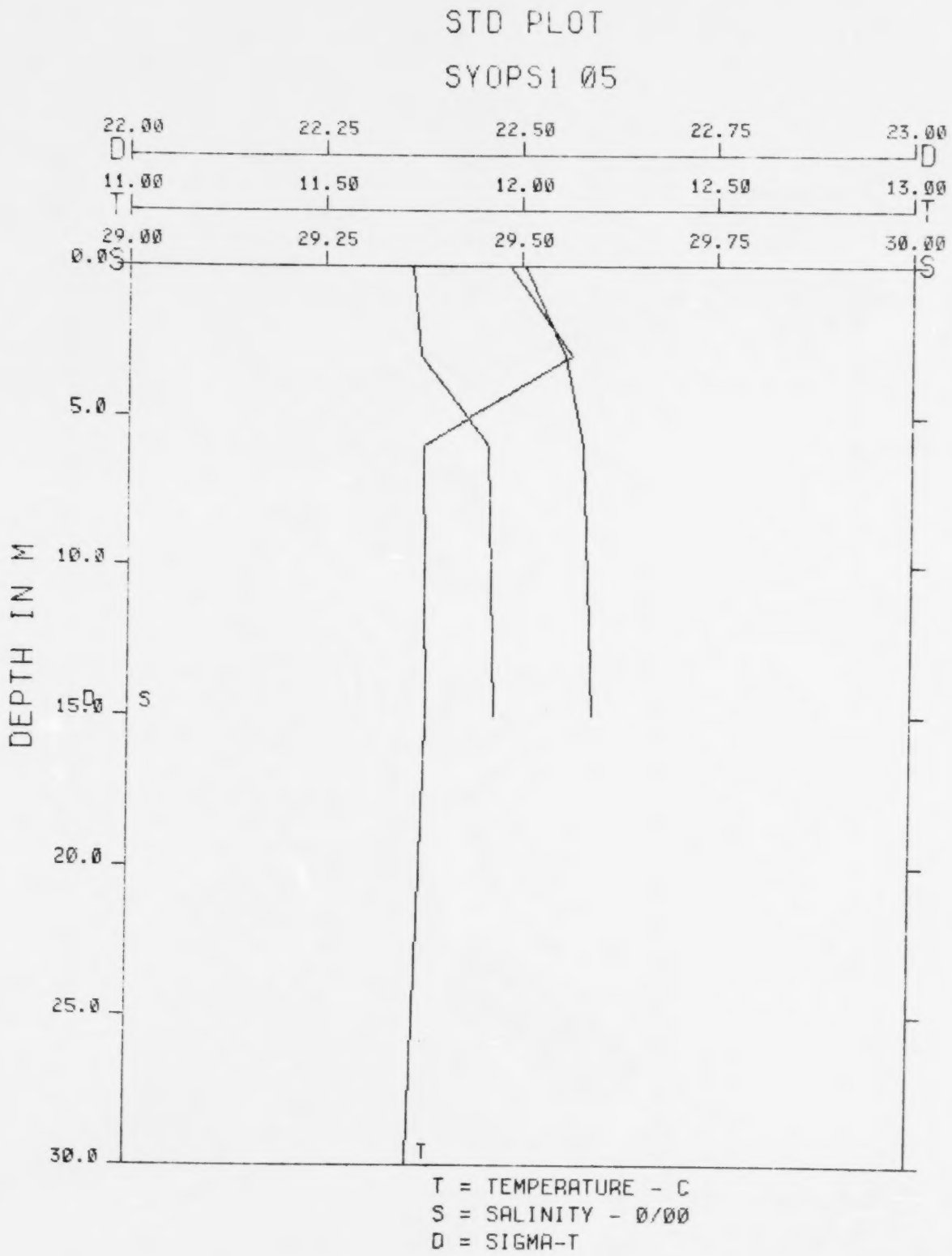
LATITUDE 47° 12 42
LONGITUDE 123° 04 24

STATION DATE 07/02/73
SECCHI 01.5 M

0	2.158	
5		
10	1.031	2.17
15		

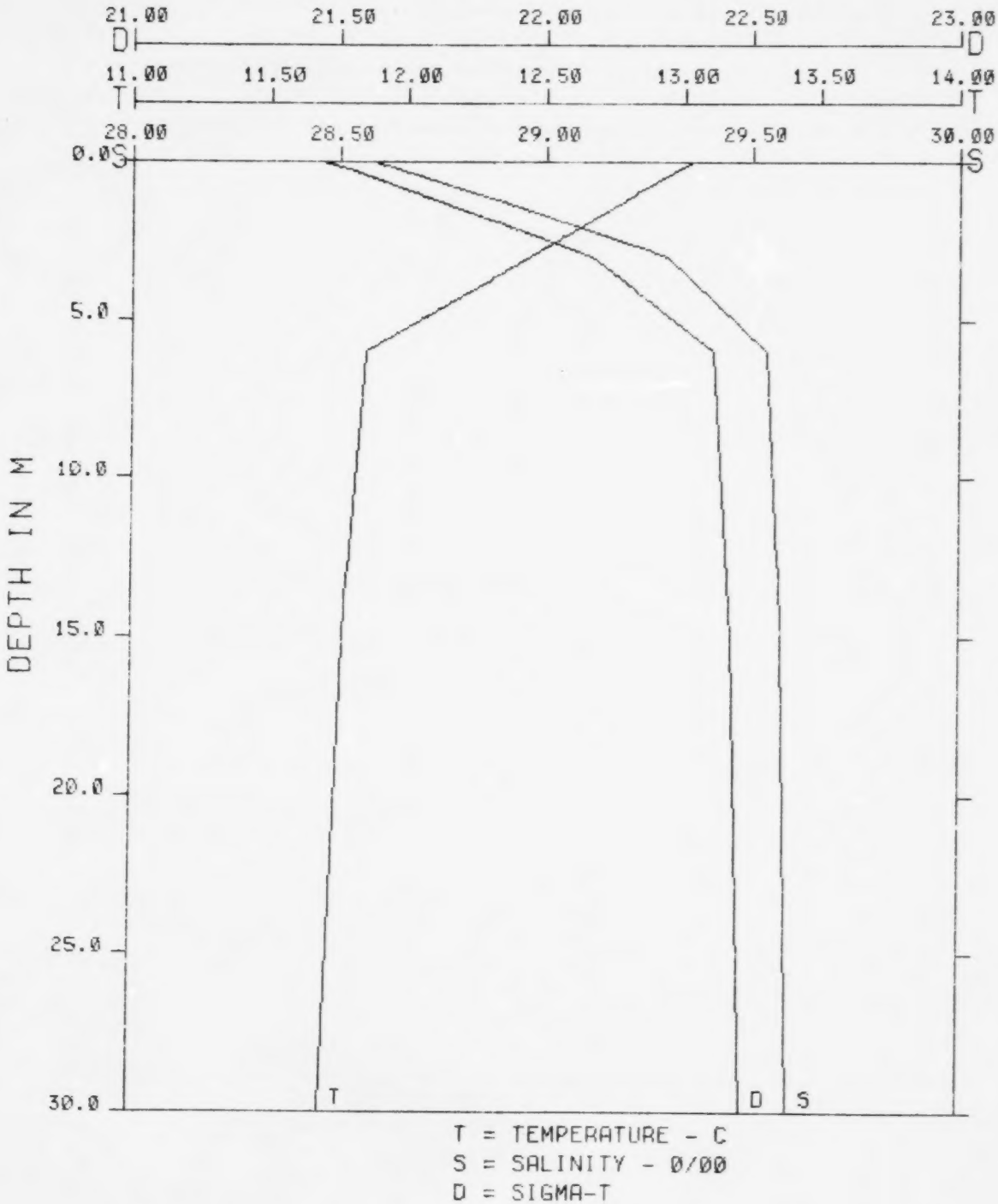
SALINITY - TEMPERATURE - DEPTH PROFILES

(SYOPS 1, 3)


STD PLOT
SYOPS1 Ø5
22.00
22.25
22.50
22.75
23.00
D
D
11.00
11.50
12.00
12.50
13.00
T
T
29.00
29.25
29.50
29.75
30.00
0.0
S
S
5.0
10.0
15.0
S
D
20.0
25.0
30.0
T
DEPTH IN M
T = TEMPERATURE - C
S = SALINITY - Ø/ØØ
D = SIGMA-T

STD PLOT

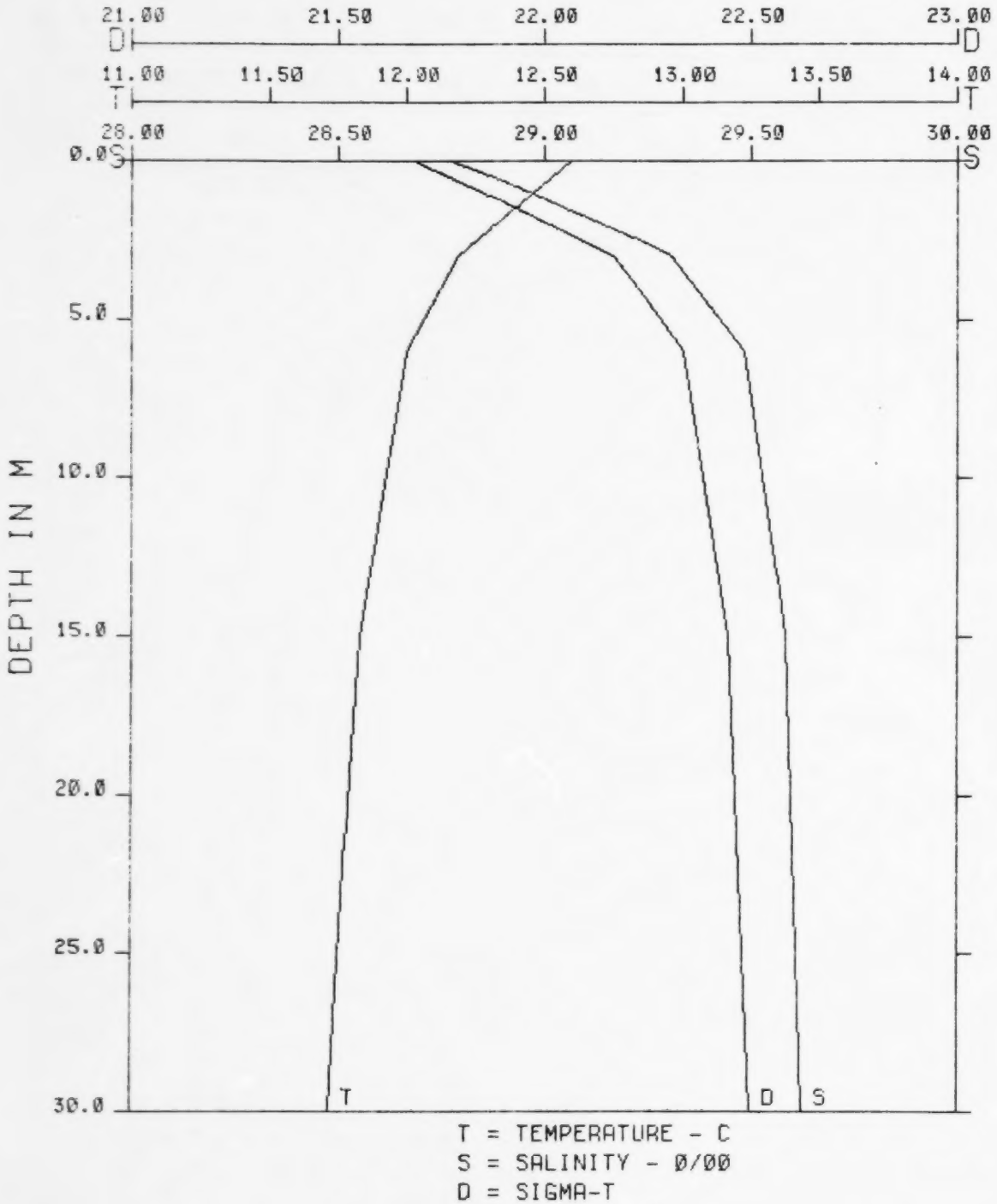
SYOPS1 Ø6



T = TEMPERATURE - C
S = SALINITY - Ø/ØØ
D = SIGMA-T

STD PLOT

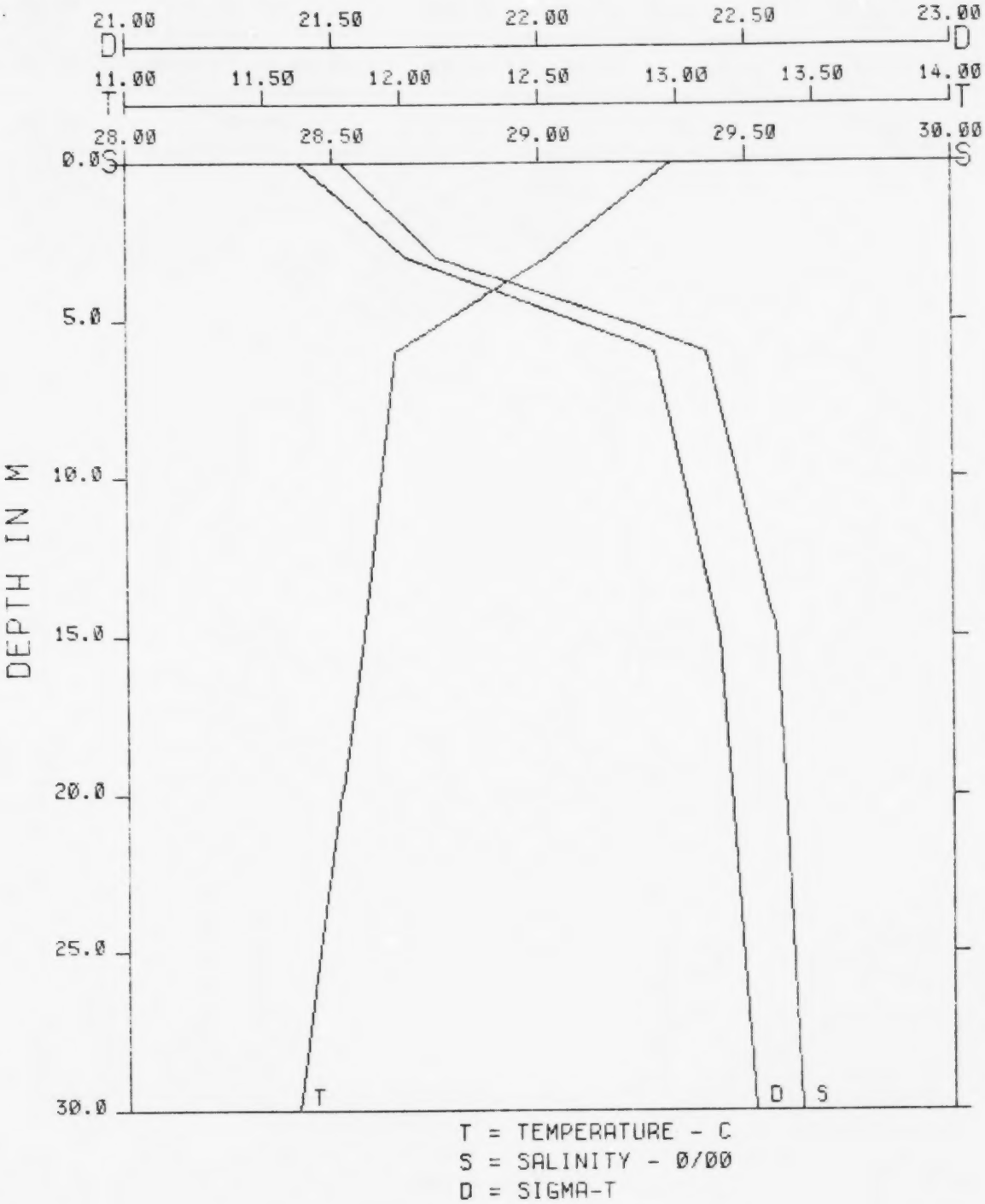
SYOPS1 Ø7



T = TEMPERATURE - C
S = SALINITY - Ø/ØØ
D = SIGMA-T

STD PLOT

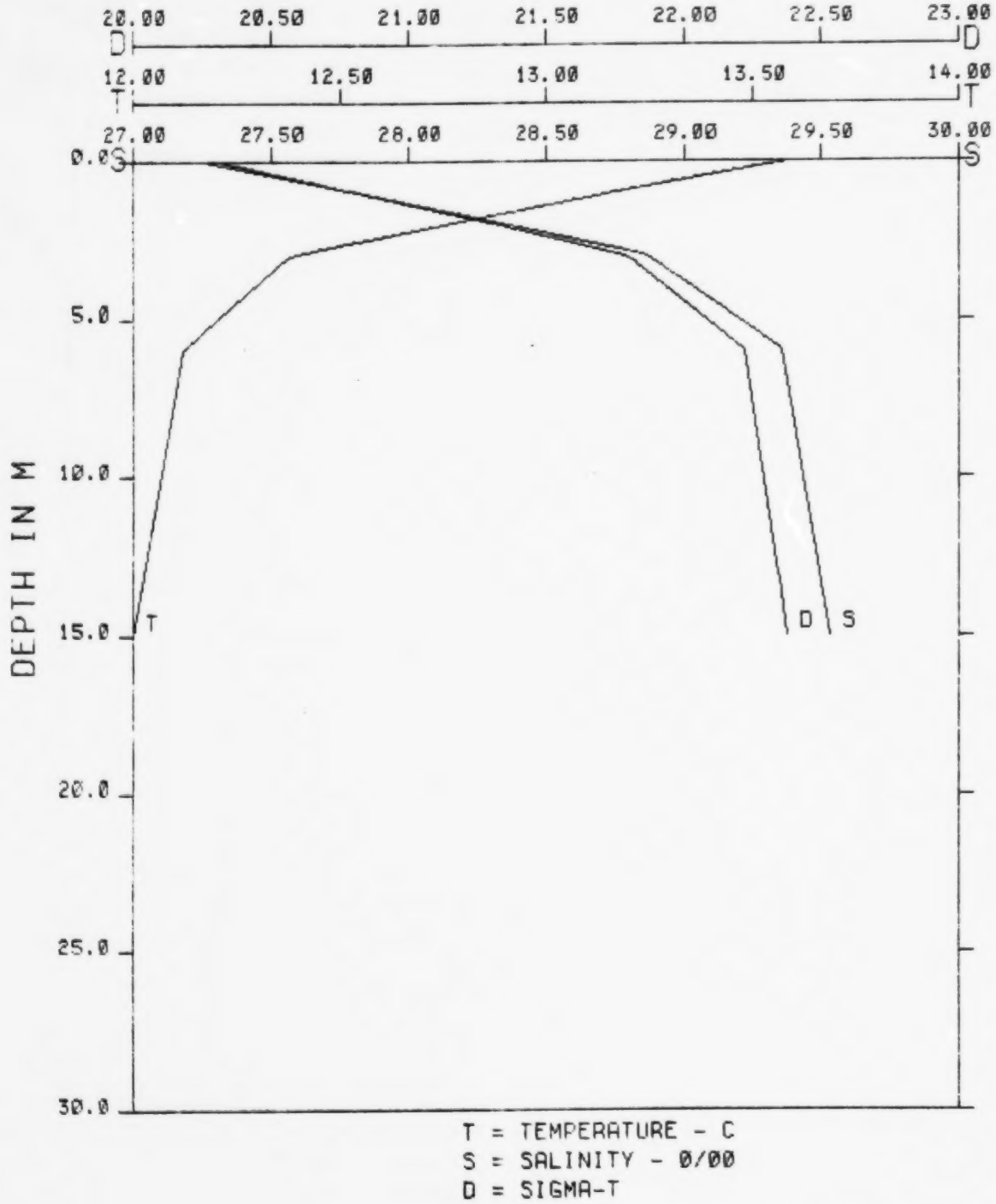
SYOPS1 11



T = TEMPERATURE - C
S = SALINITY - Ø/ØØ
D = SIGMA-T

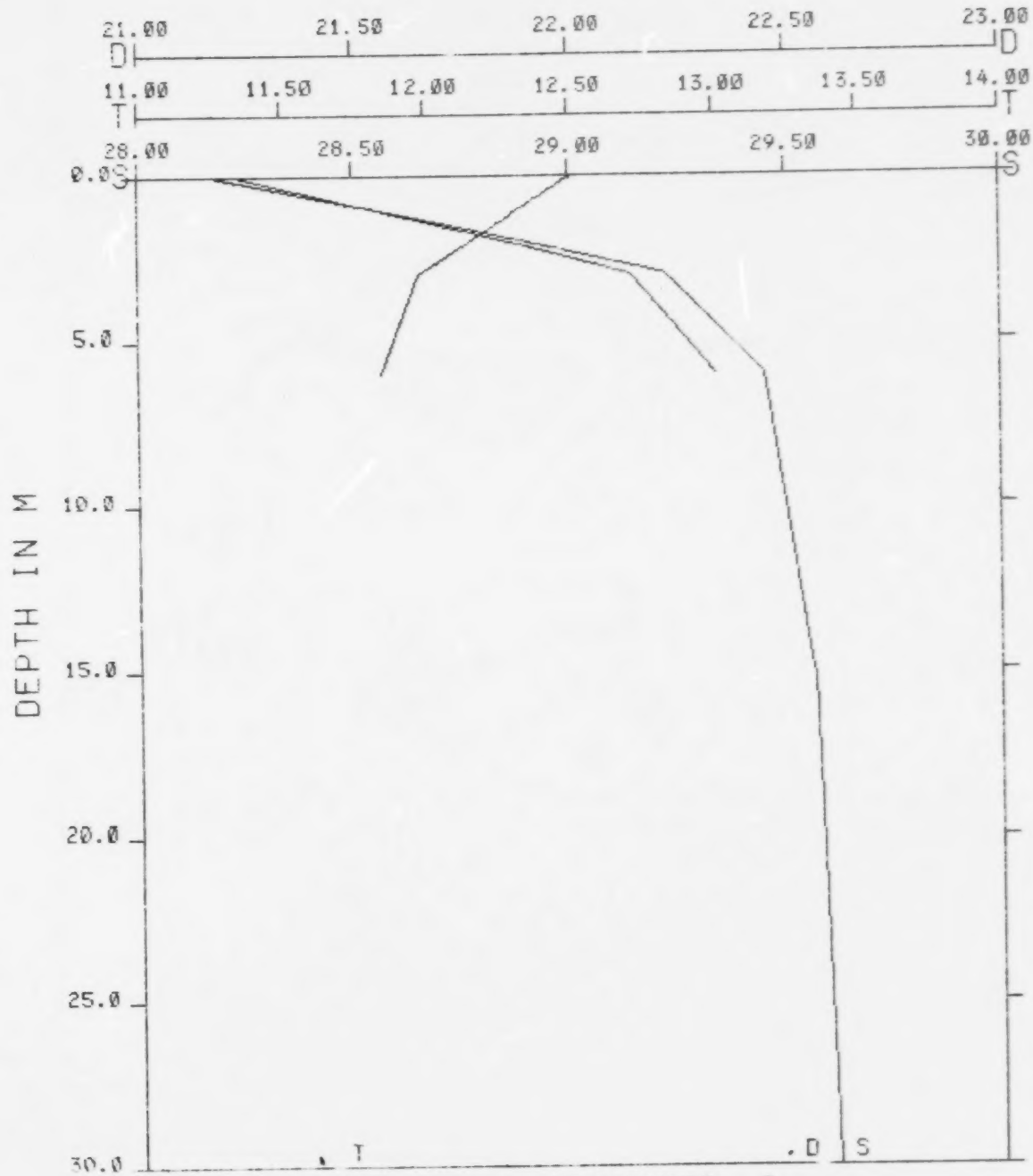
STD PLOT

SYOPS1 12



STD PLOT

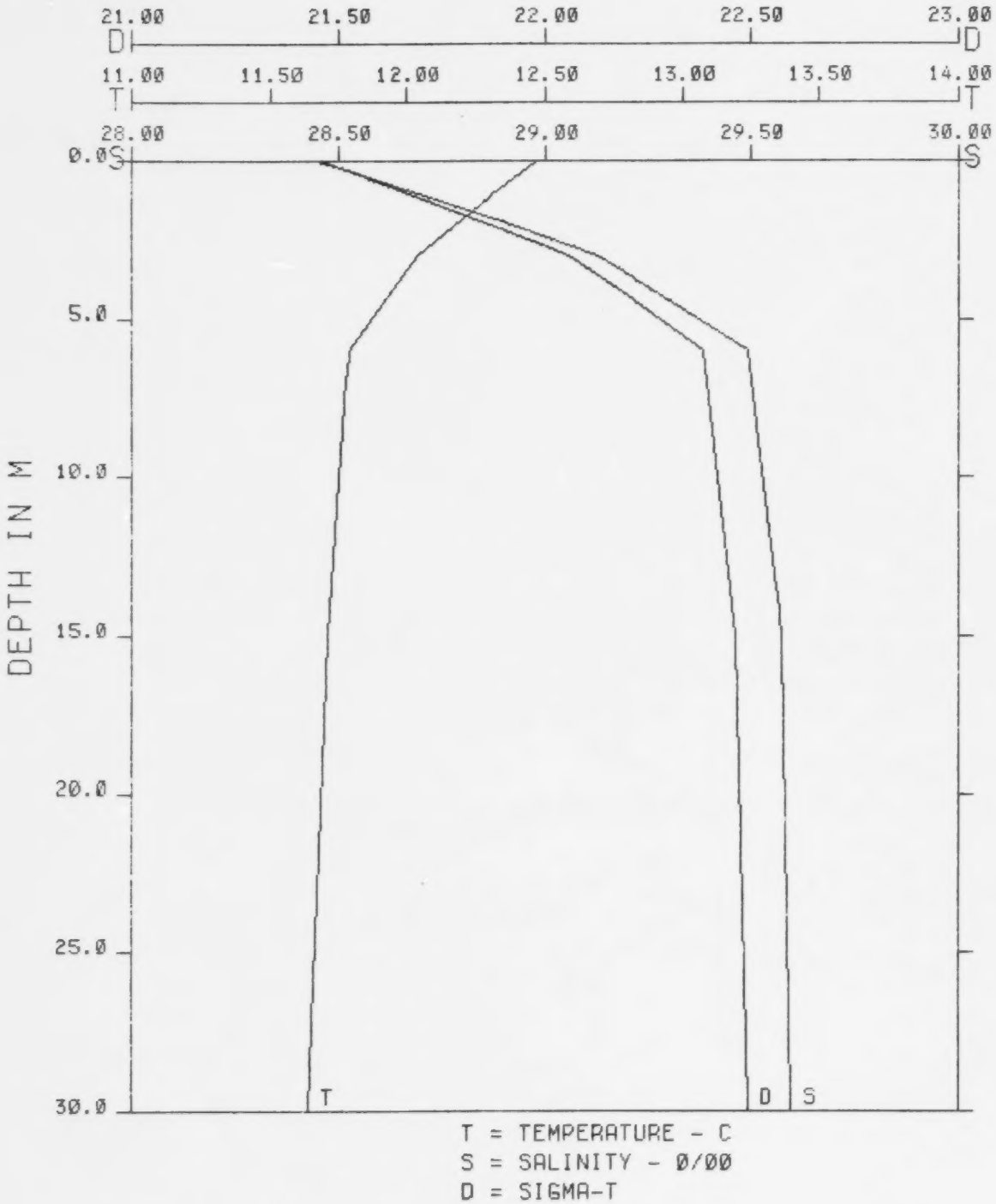
SYOPS1 14



T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T

STD PLOT

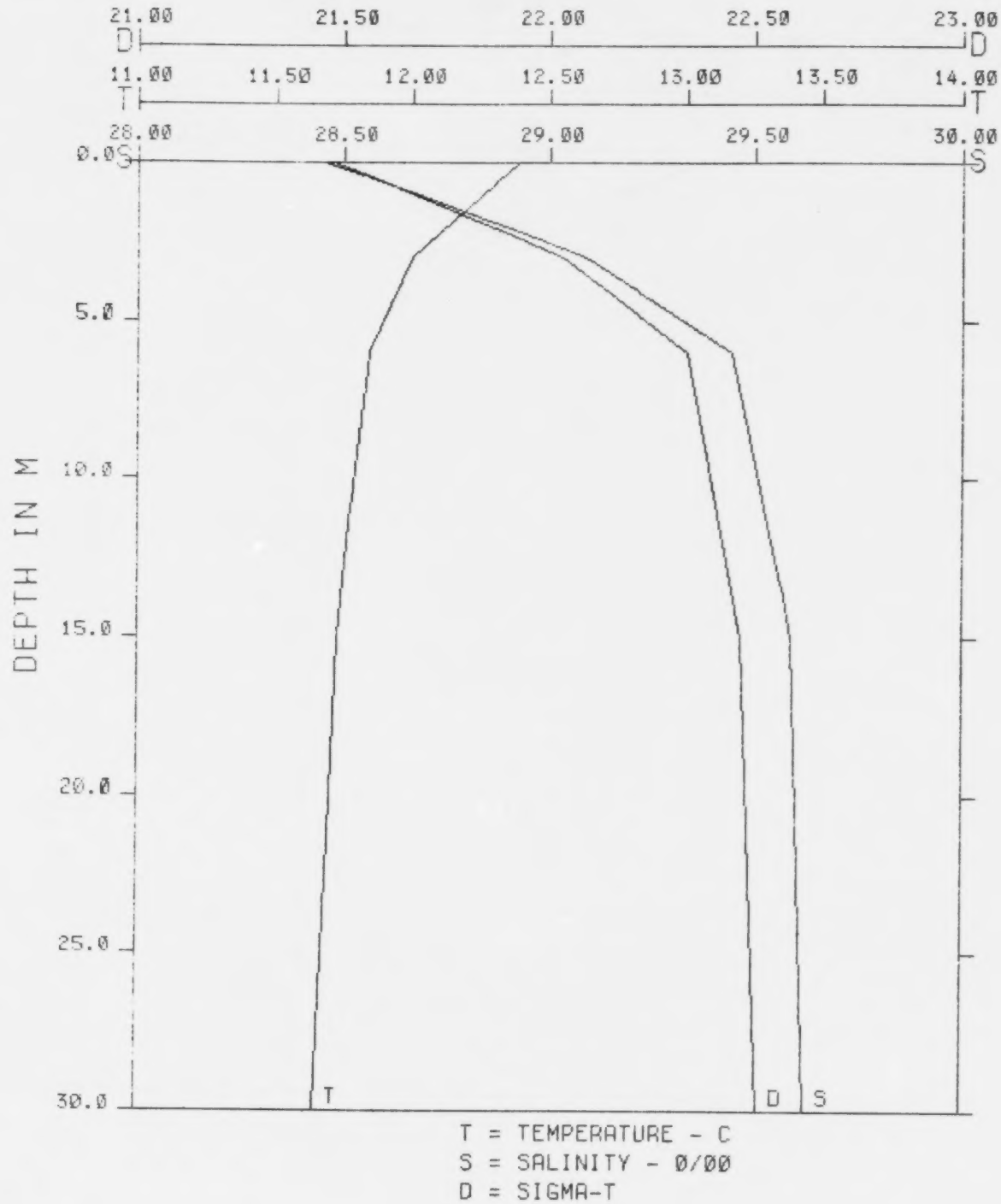
SYOPS1 15



T = TEMPERATURE - C
S = SALINITY - Ø/ØØ
D = SIGMA-T

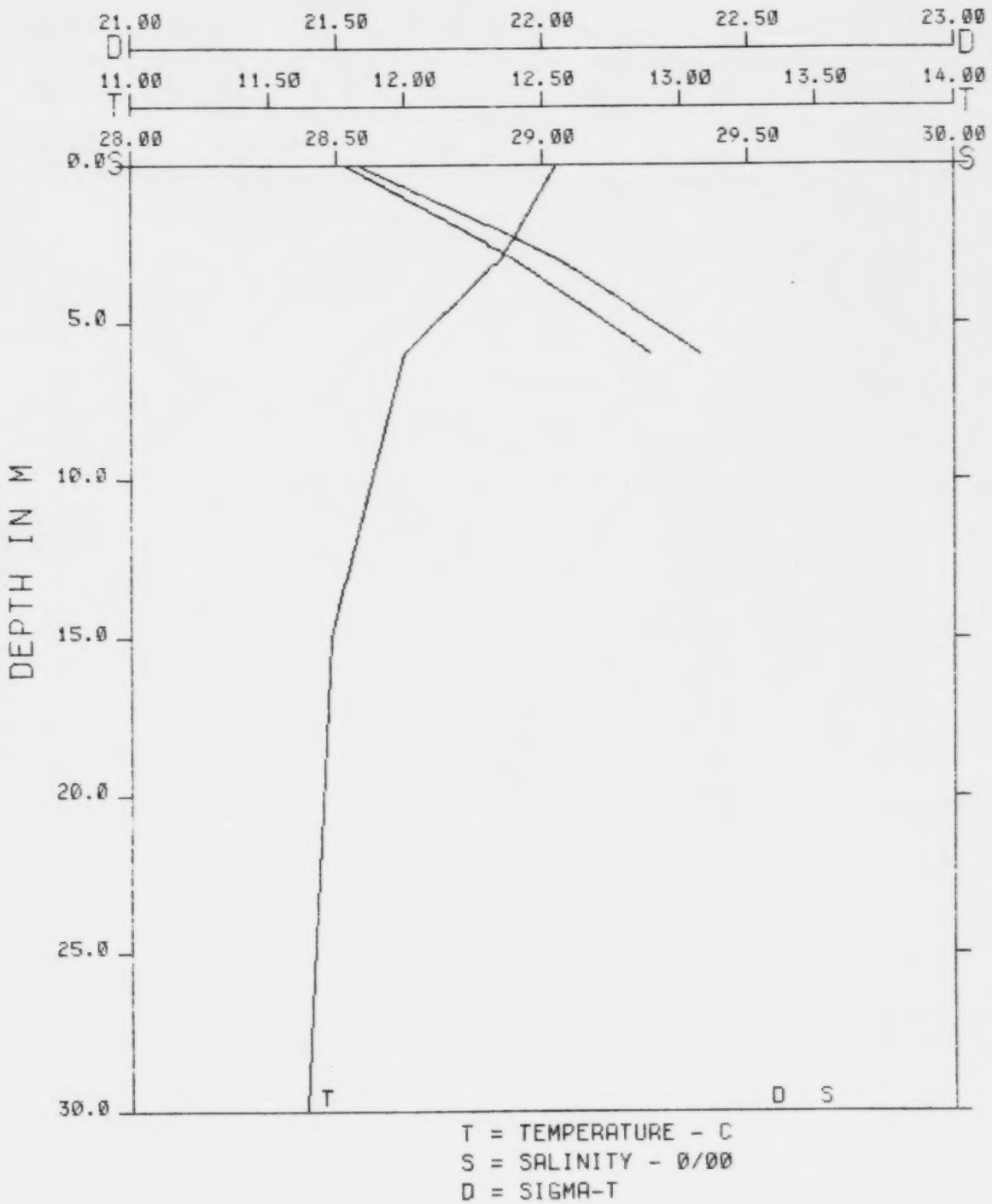
STD PLOT

SYOPS1 16

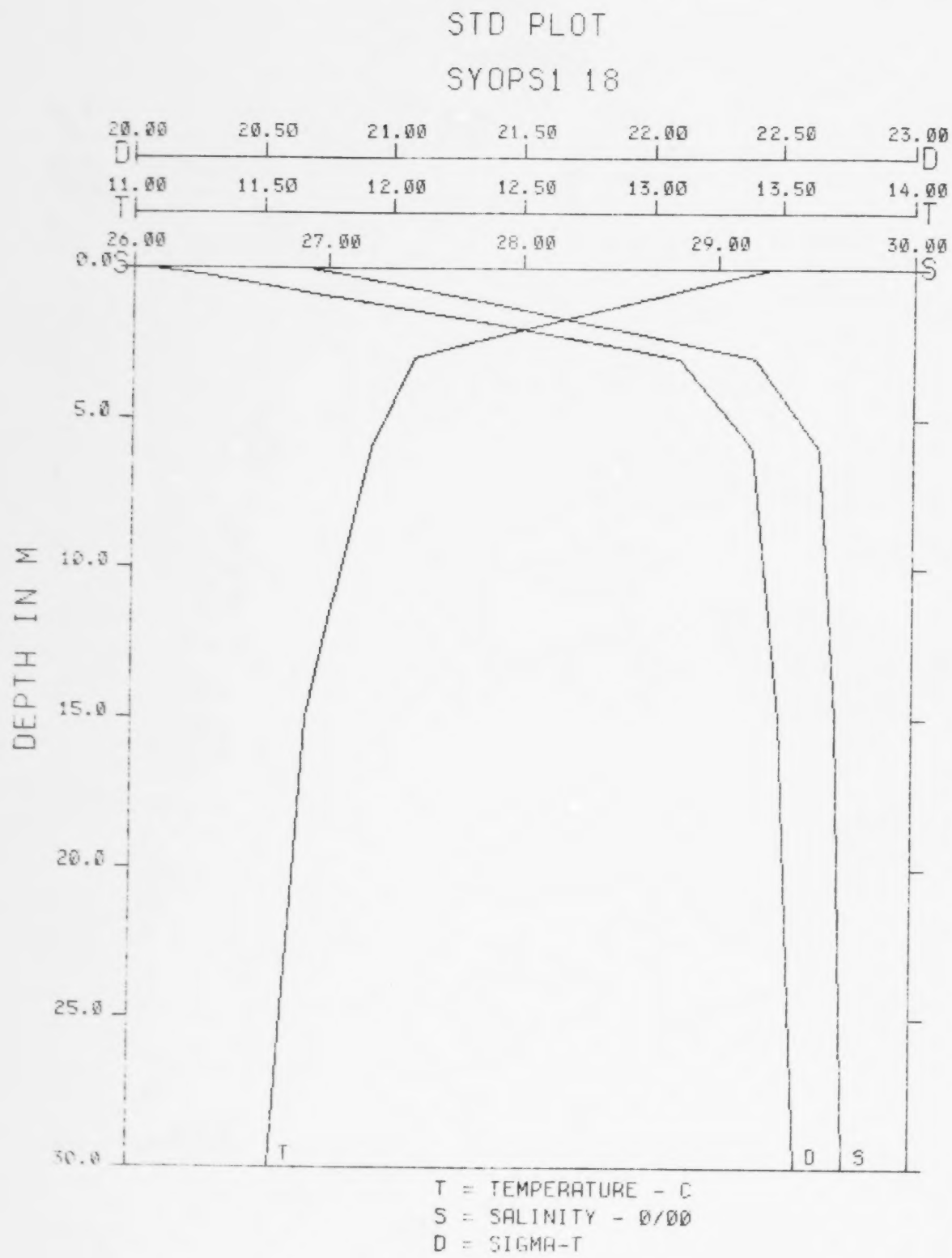


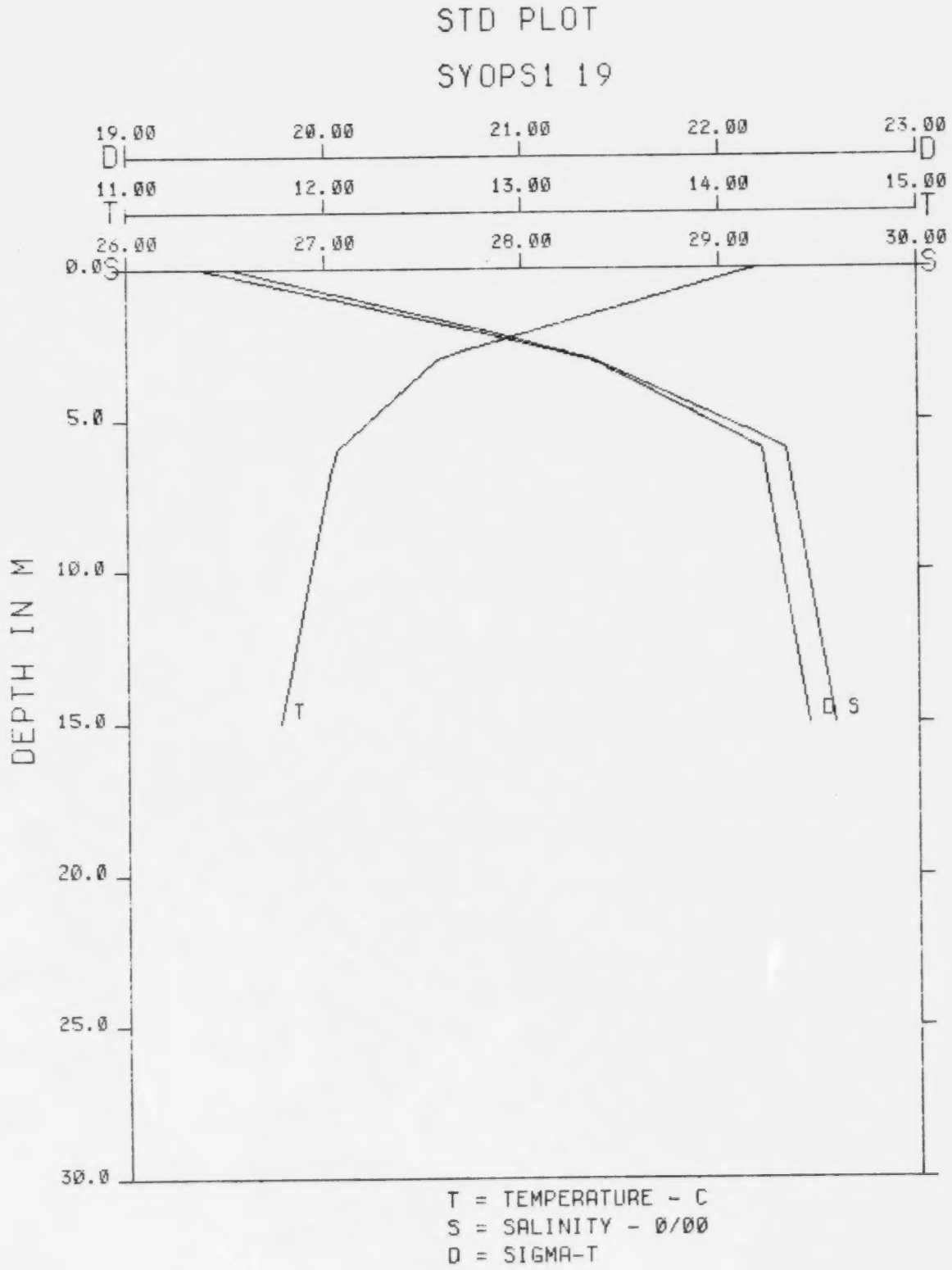
STD PLOT

SYOPS1 17



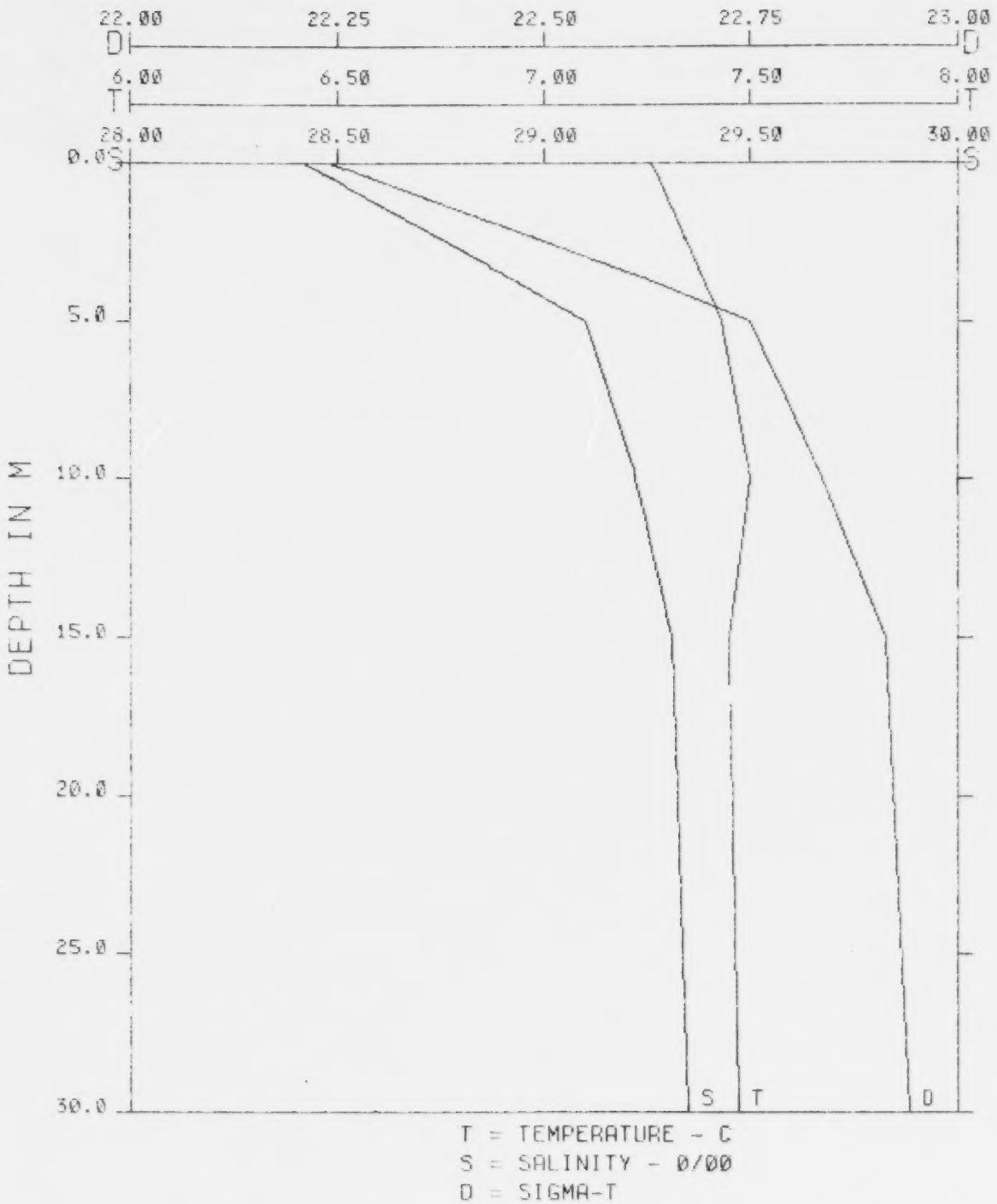
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T


STD PLOT
SYOPS1 18
20.00
20.50
21.00
21.50
22.00
22.50
23.00
D
D
11.00
11.50
12.00
12.50
13.00
13.50
14.00
T
T
26.00
27.00
28.00
29.00
30.00
0.0
S
S
5.0
10.0
15.0
20.0
25.0
30.0
DEPTH IN M
T
D
S
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T


STD PLOT
SYOPS1 19
19.00
20.00
21.00
22.00
23.00
D
D
11.00
12.00
13.00
14.00
15.00
T
T
26.00
27.00
28.00
29.00
30.00
0.0
S
S
5.0
10.0
15.0
20.0
25.0
30.0
DEPTH IN M
T
D
S
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T

STD PLOT

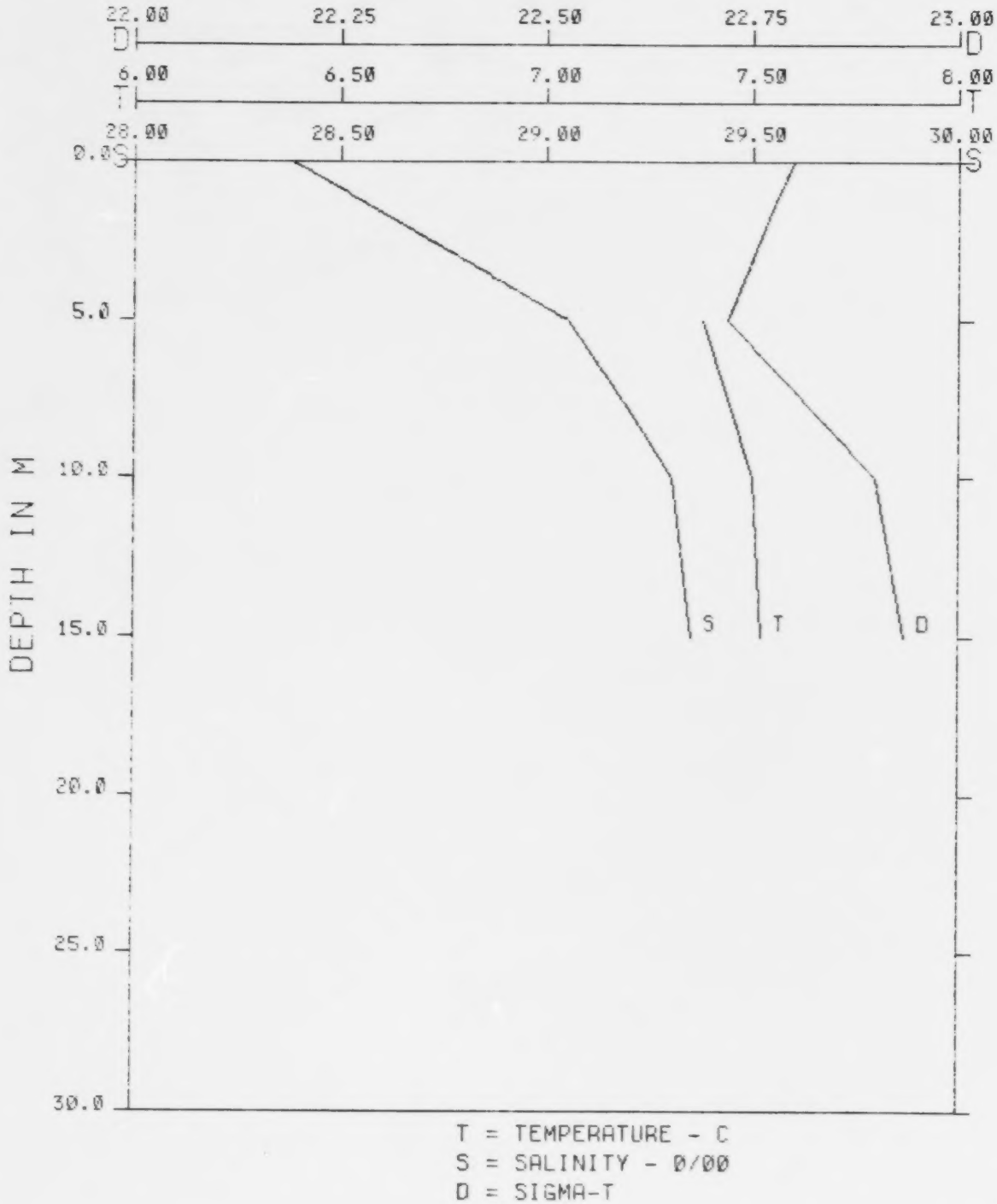
SYOPS3 21



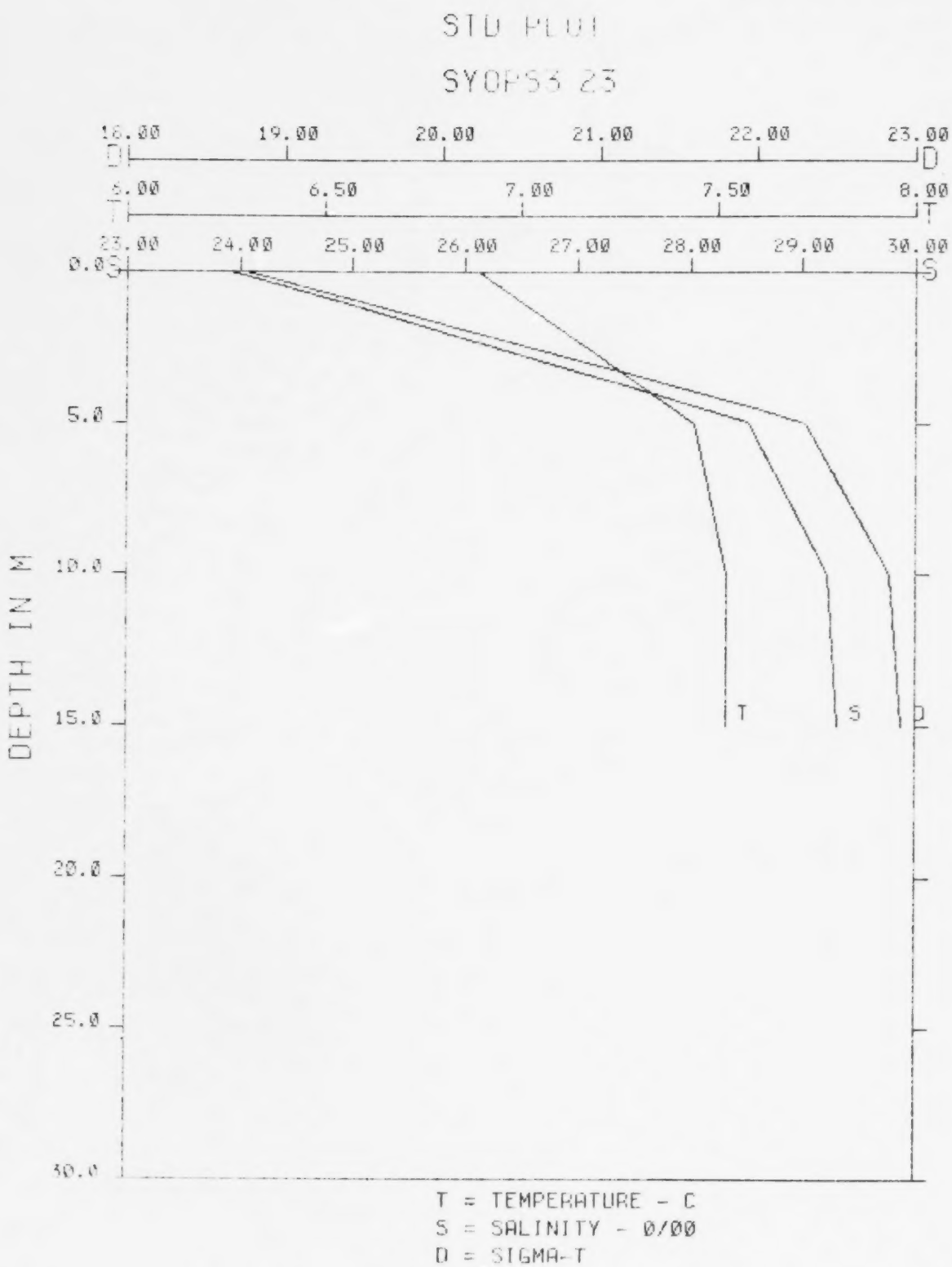
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T

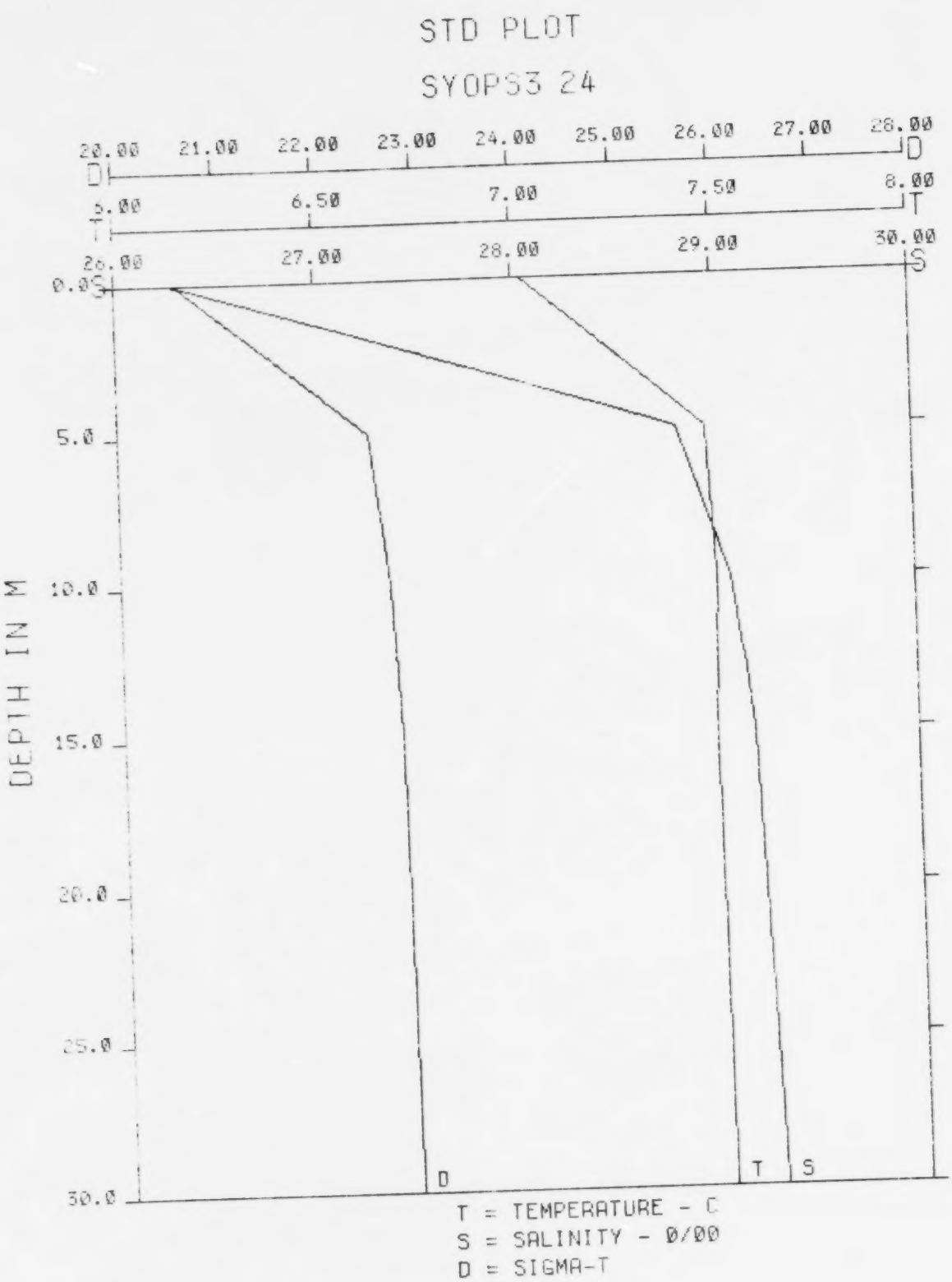
STD PLOT

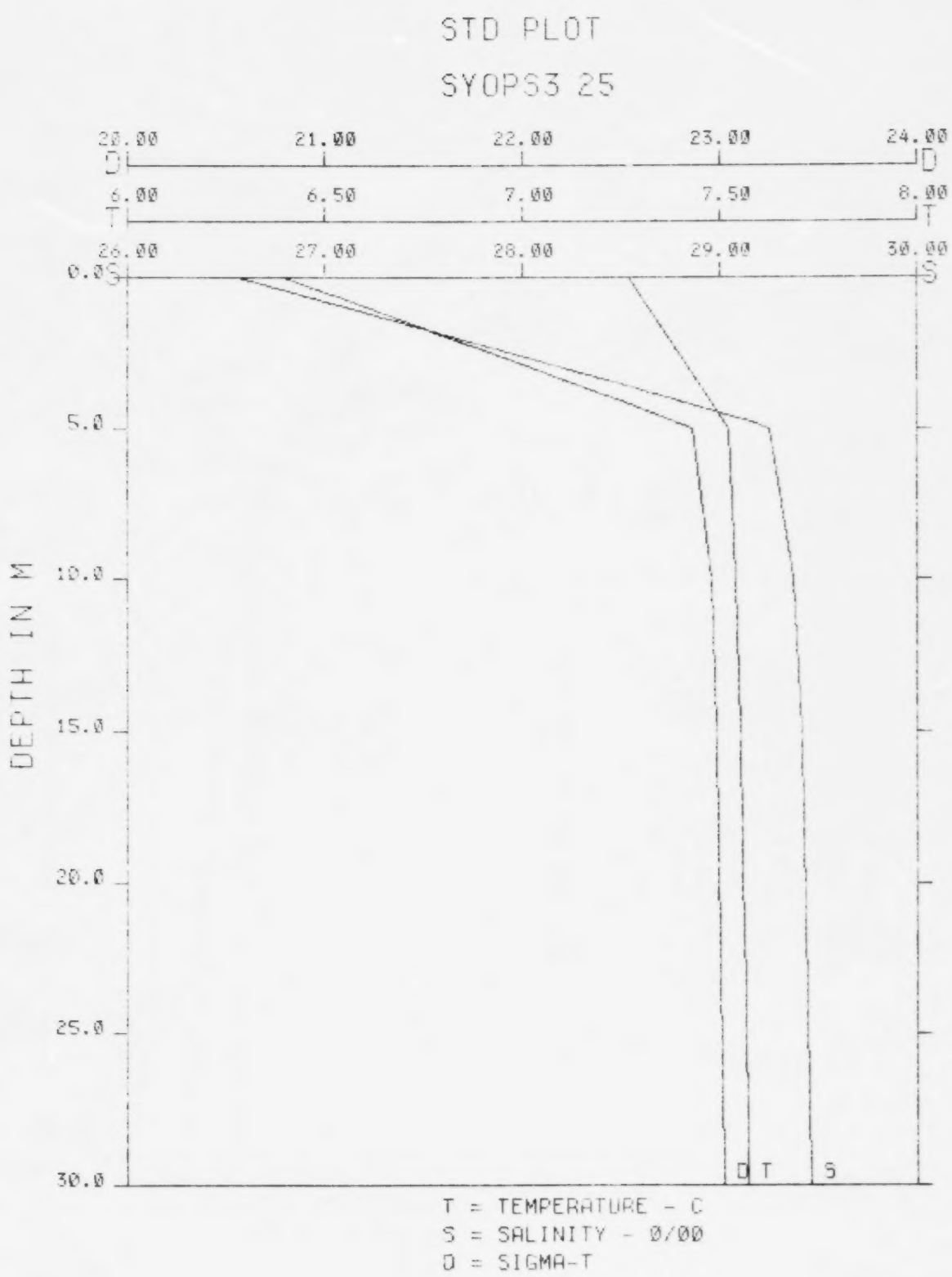
SYOPS3 22.



T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T

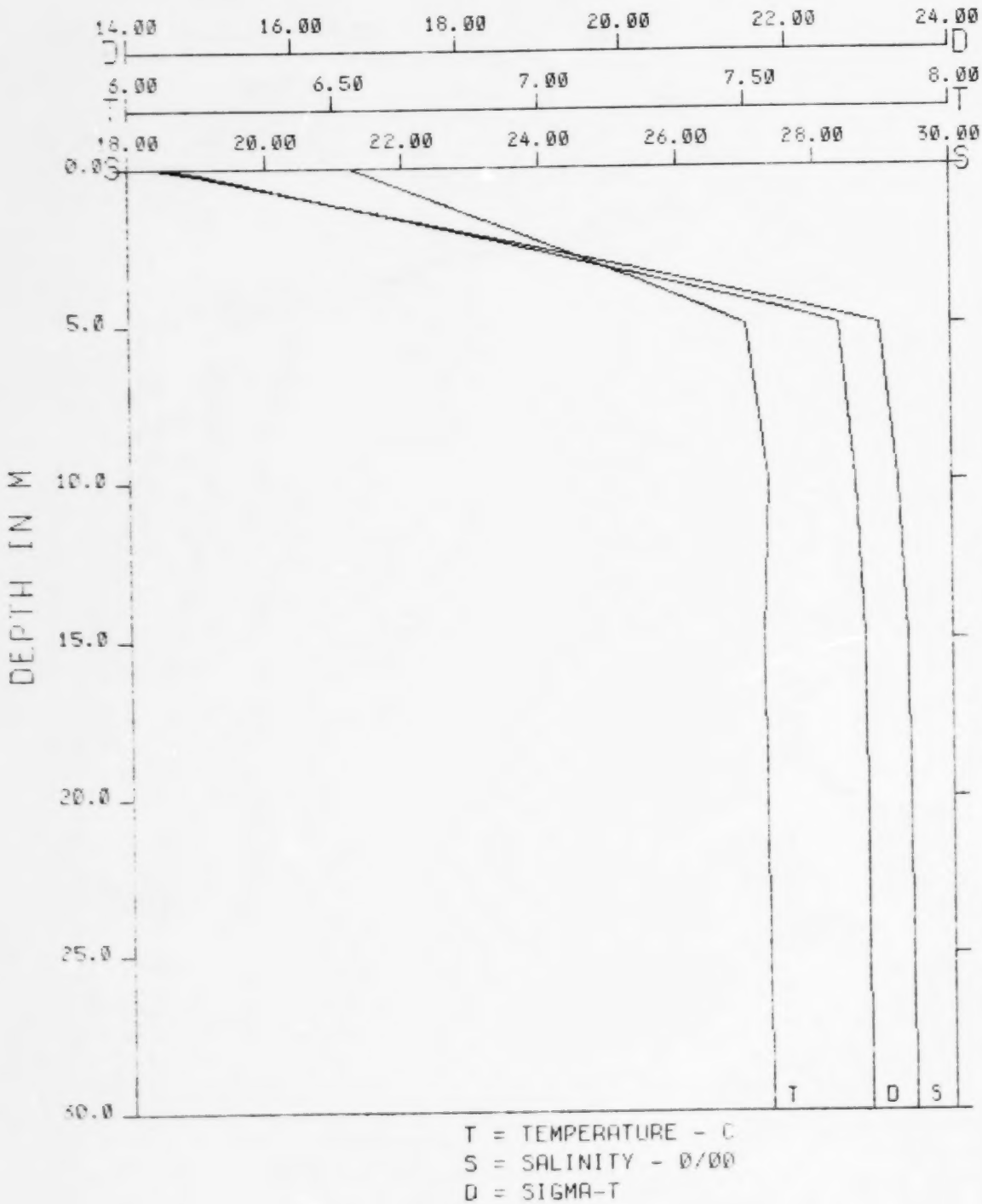

STD PLOT
SYOPSS 23
16.00
19.00
20.00
21.00
22.00
23.00
D
6.00
6.50
7.00
7.50
8.00
T
23.00
24.00
25.00
26.00
27.00
28.00
29.00
30.00
S
0.0
5.0
10.0
15.0
20.0
25.0
30.0
DEPTH IN M
T
S
D
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T


STD PLOT
SYOPS3 24
20.00
21.00
22.00
23.00
24.00
25.00
26.00
27.00
28.00
D
5.00
6.50
7.00
7.50
8.00
T
26.00
27.00
28.00
29.00
30.00
S
0.0
5.0
10.0
15.0
20.0
25.0
30.0
DEPTH IN M
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T


STD PLOT
SYOPS3 25
20.00
21.00
22.00
23.00
24.00
D
6.00
6.50
7.00
7.50
8.00
T
26.00
27.00
28.00
29.00
30.00
S
0.0
5.0
10.0
15.0
20.0
25.0
30.0
DEPTH IN M
D T S
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T

STD PLOT

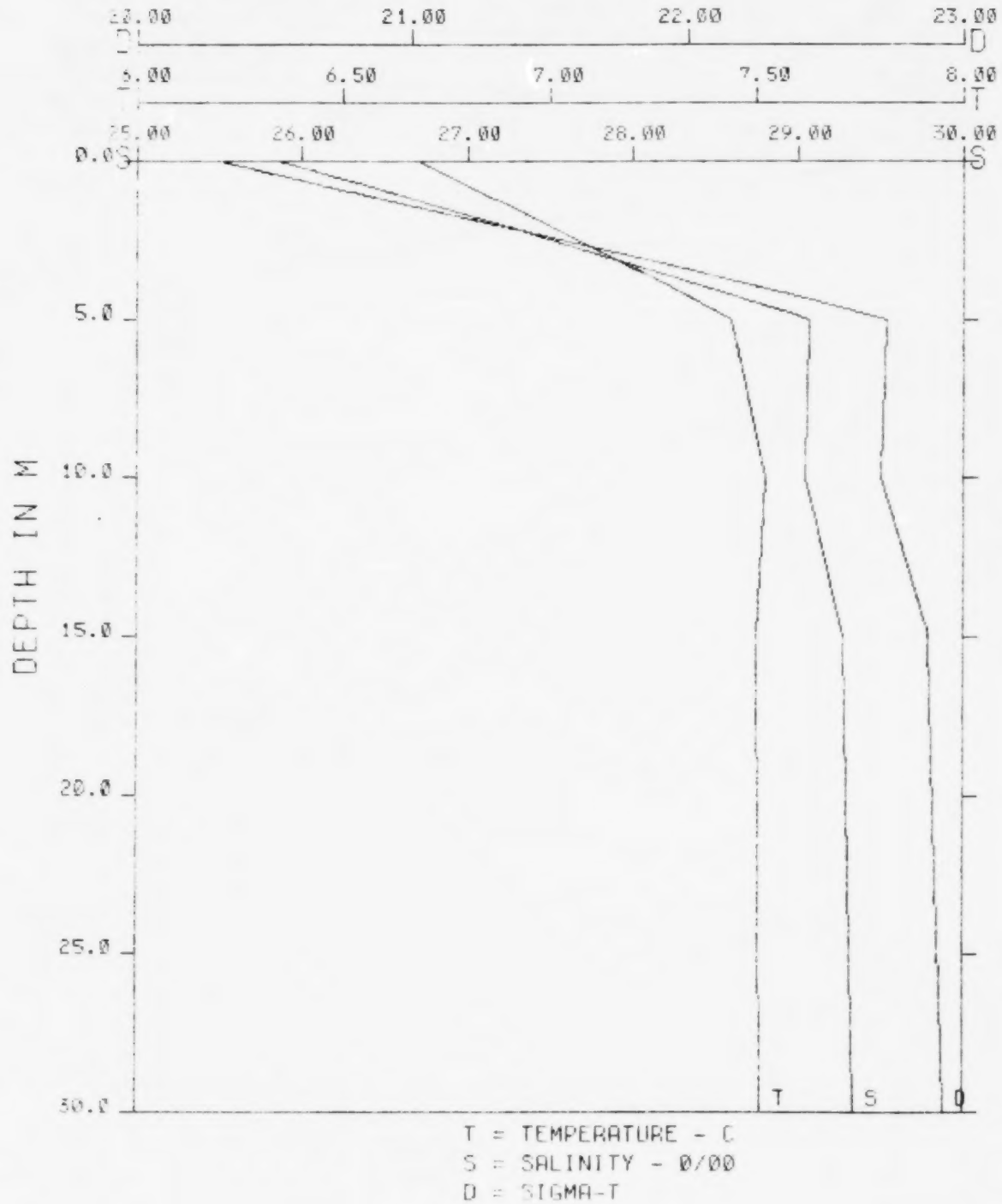
SYOPS3 26



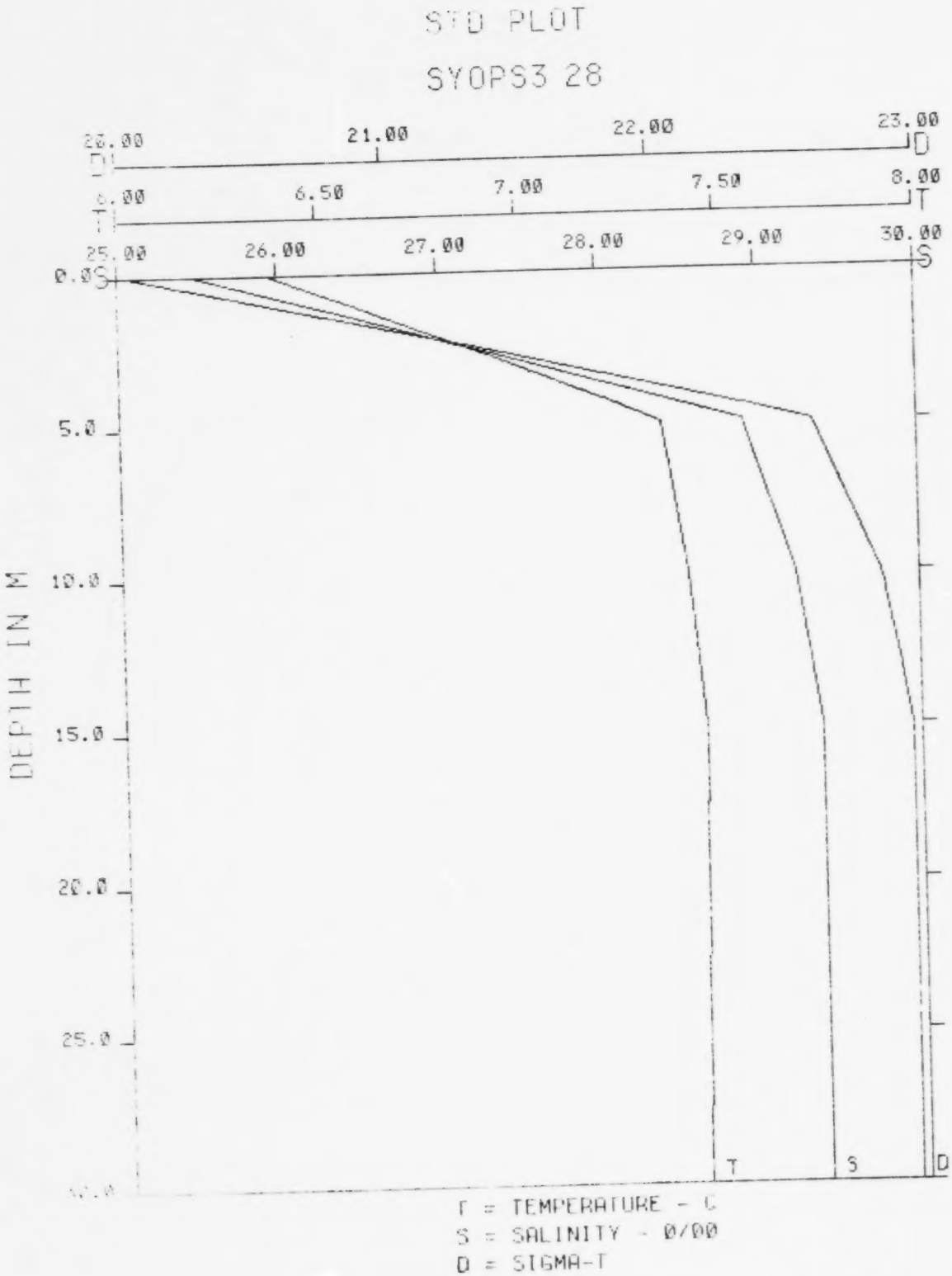
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T

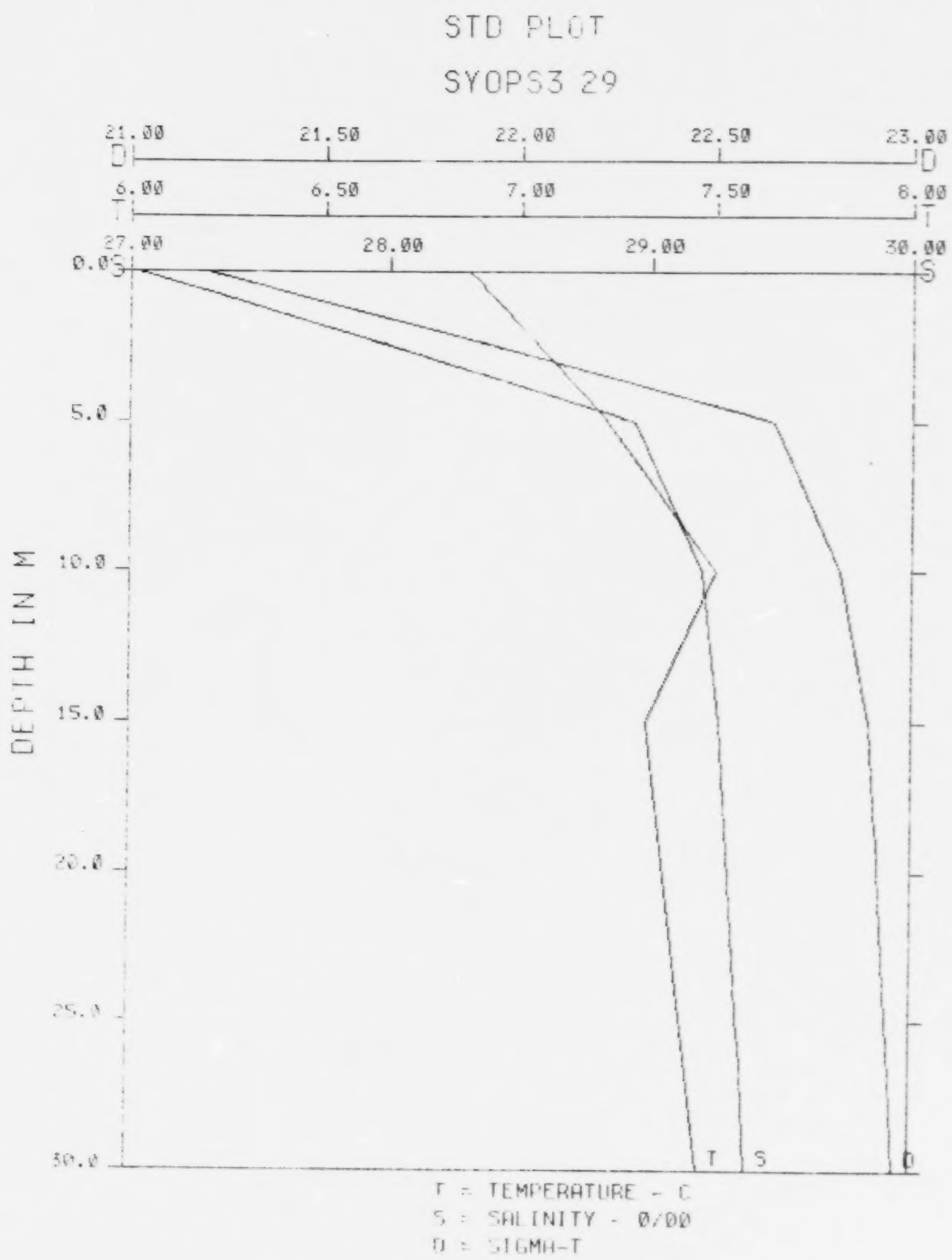
STD PLOT

SYOPS3 27



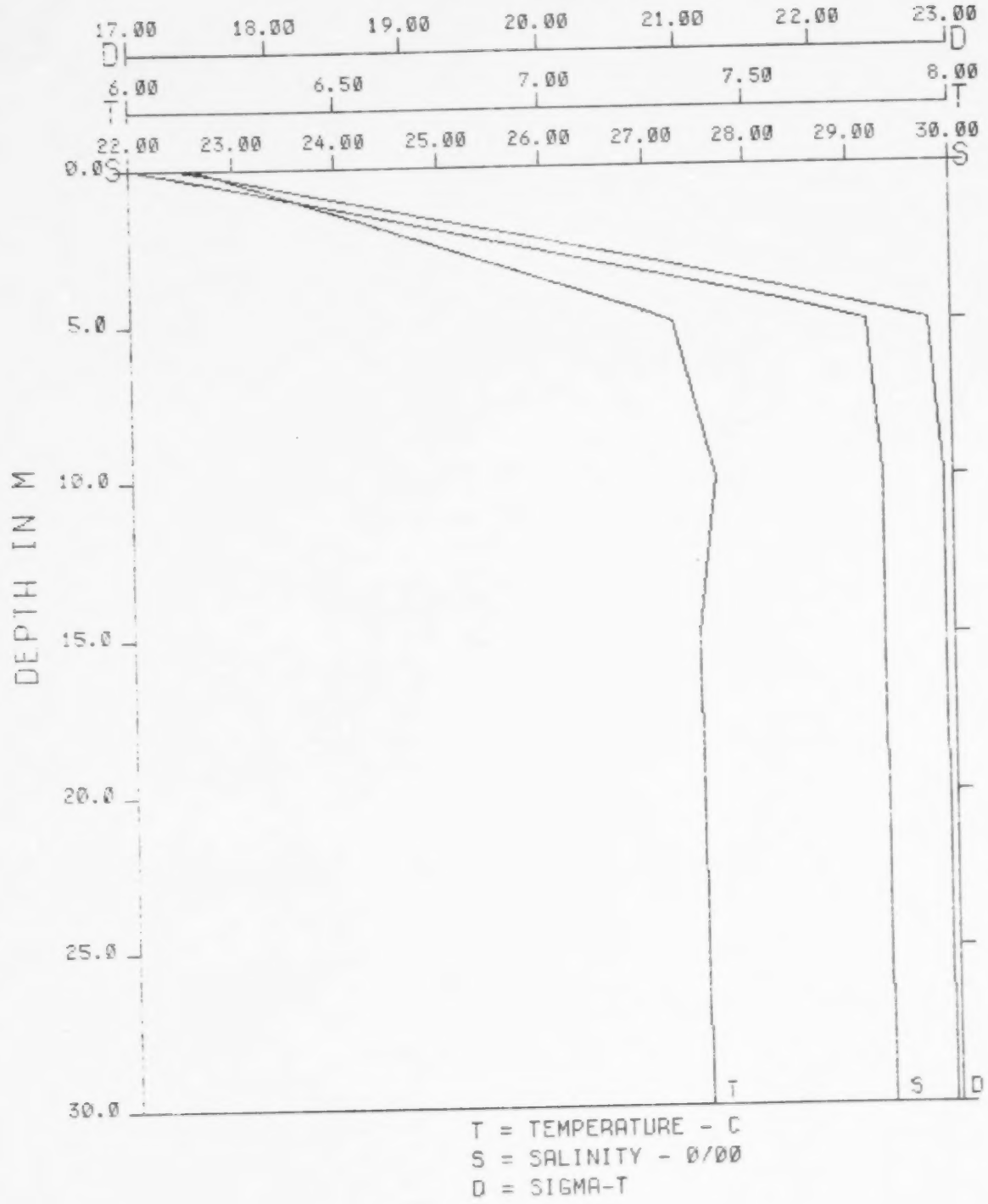
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T


STD PLOT
SYOPS3 28
20.00
21.00
22.00
23.00
D
6.00
6.50
7.00
7.50
8.00
T
25.00
26.00
27.00
28.00
29.00
30.00
S
0.0
5.0
10.0
15.0
20.0
25.0
DEPTH IN M
T
S
D
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T


STD PLOT
SYOPS3 29
21.00
21.50
22.00
22.50
23.00
D
6.00
6.50
7.00
7.50
8.00
T
27.00
28.00
29.00
30.00
S
0.0
5.0
10.0
15.0
20.0
25.0
30.0
DEPTH IN M
T
S
D
T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T

STD PLOT

SYOPS3 30

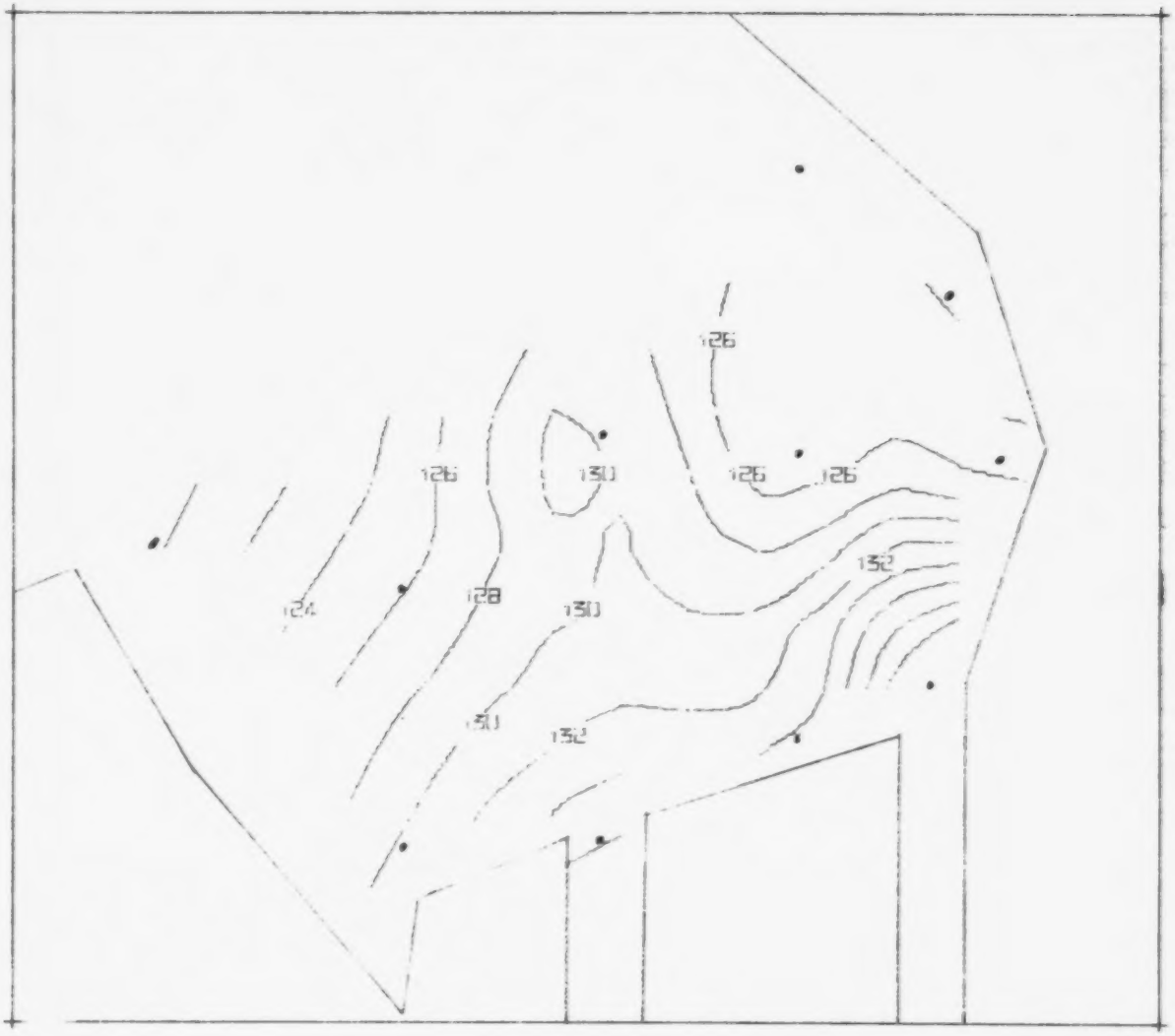


T = TEMPERATURE - C
S = SALINITY - 0/00
D = SIGMA-T

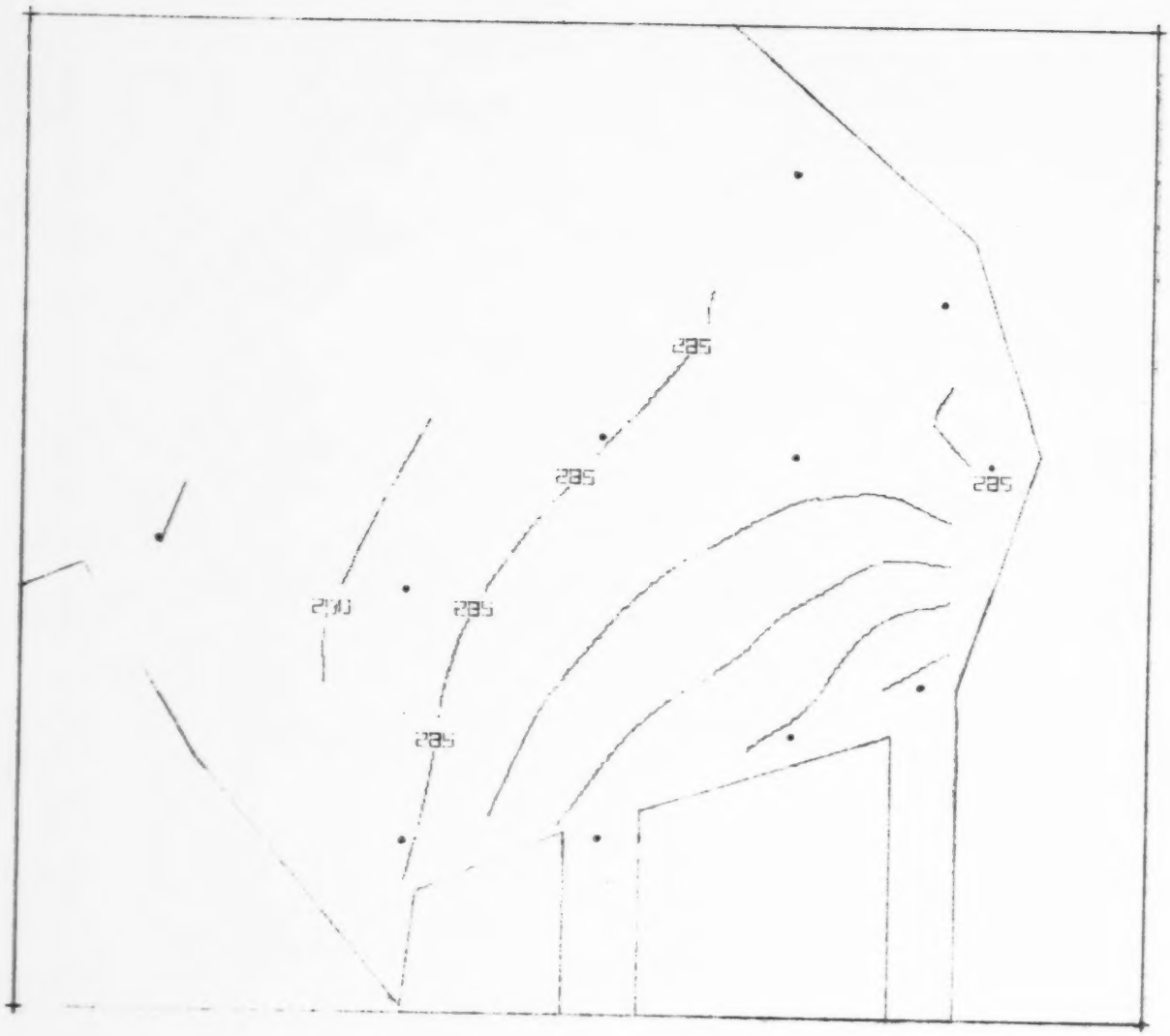
SPATIAL DISTRIBUTION OF VARIABLES

HORIZONTAL CONTOUR PLOTS (SYOPS-1)

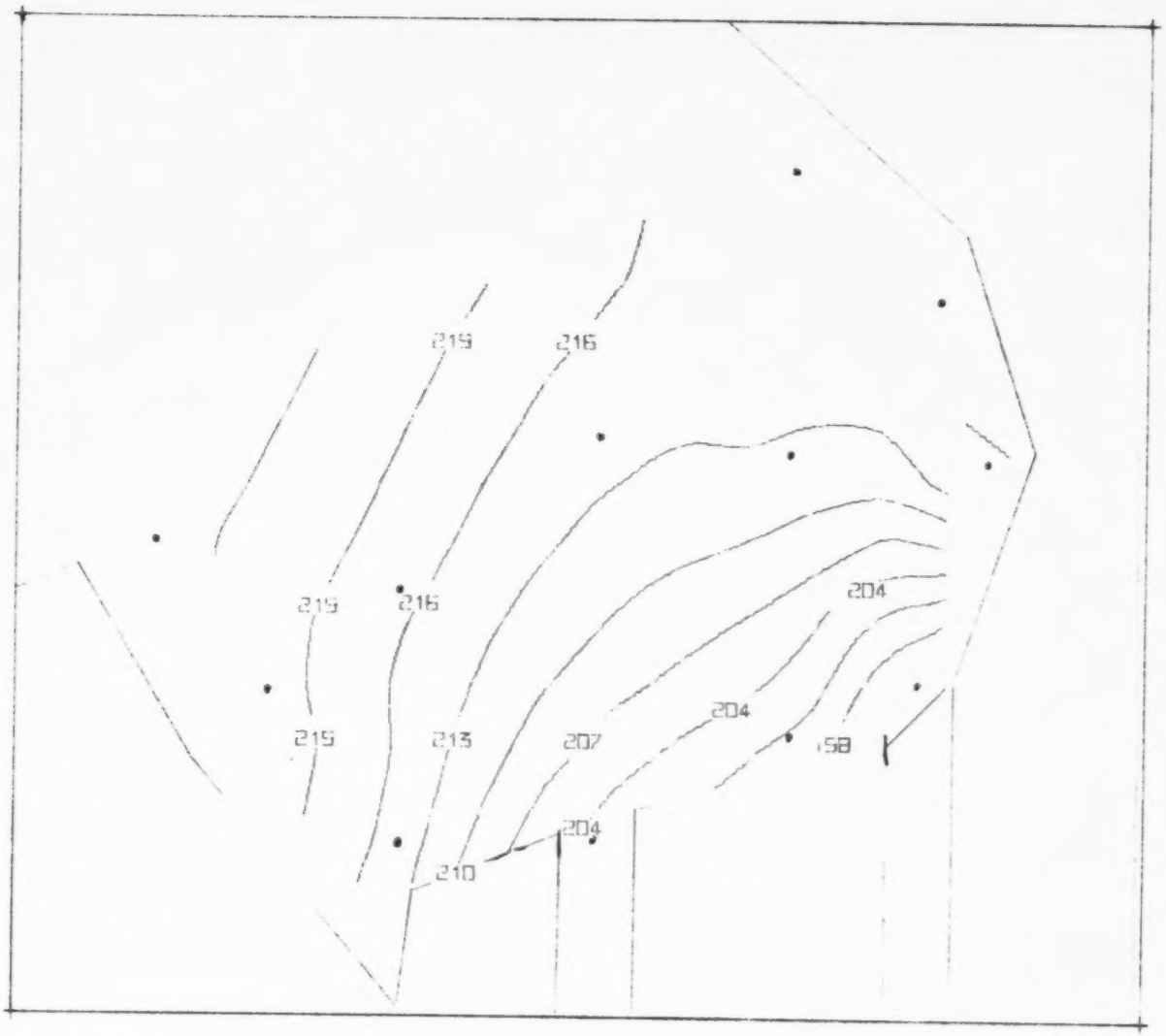
00 Meter Surface



SYOPS I TEMPERATURE OM 0.1 DEG-CENT



SYDSM. T SURFACE SALINITY PPM



SYCOM 1 SIGMA-T + 1 SIGMA-T UNIT OM

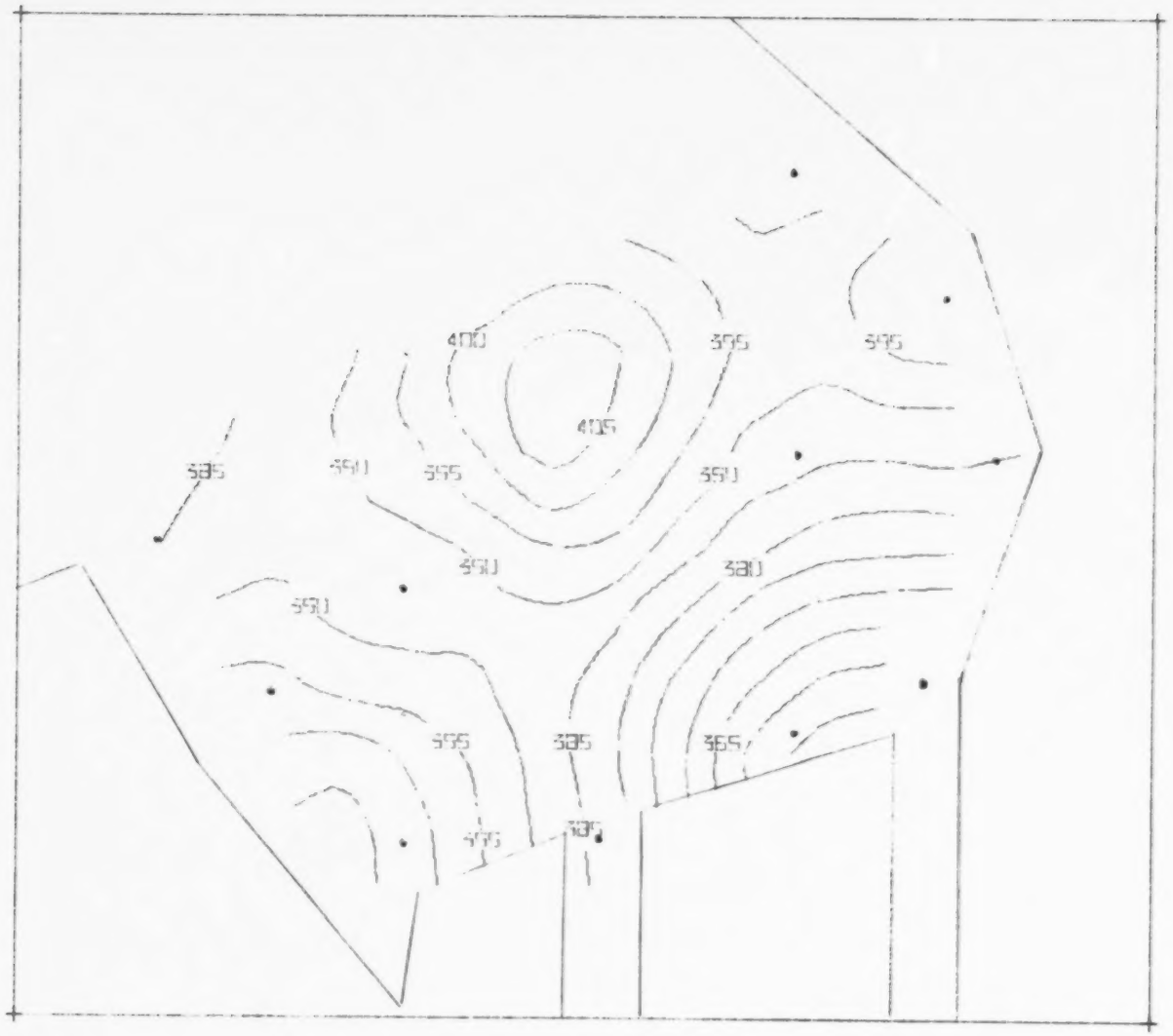
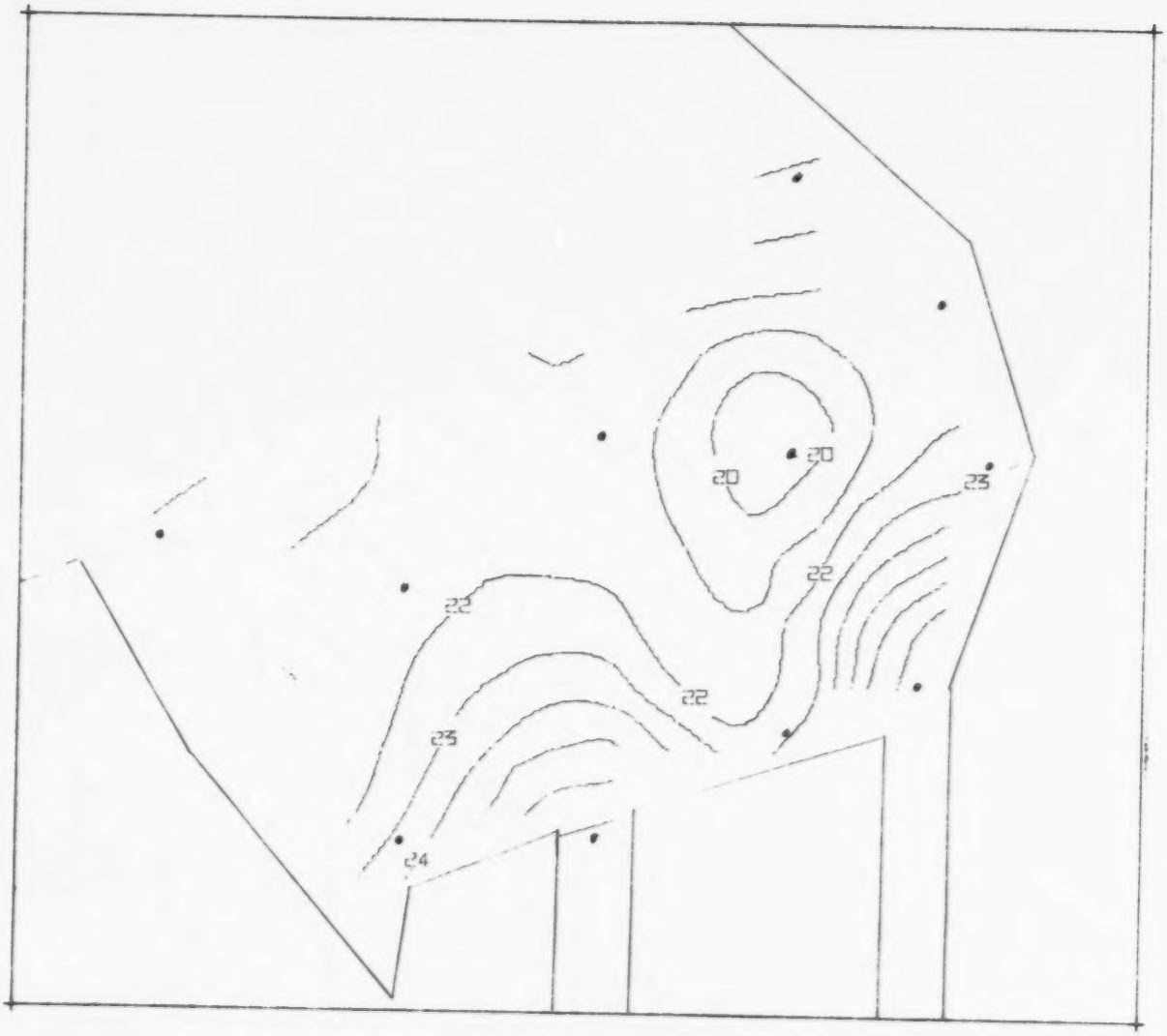
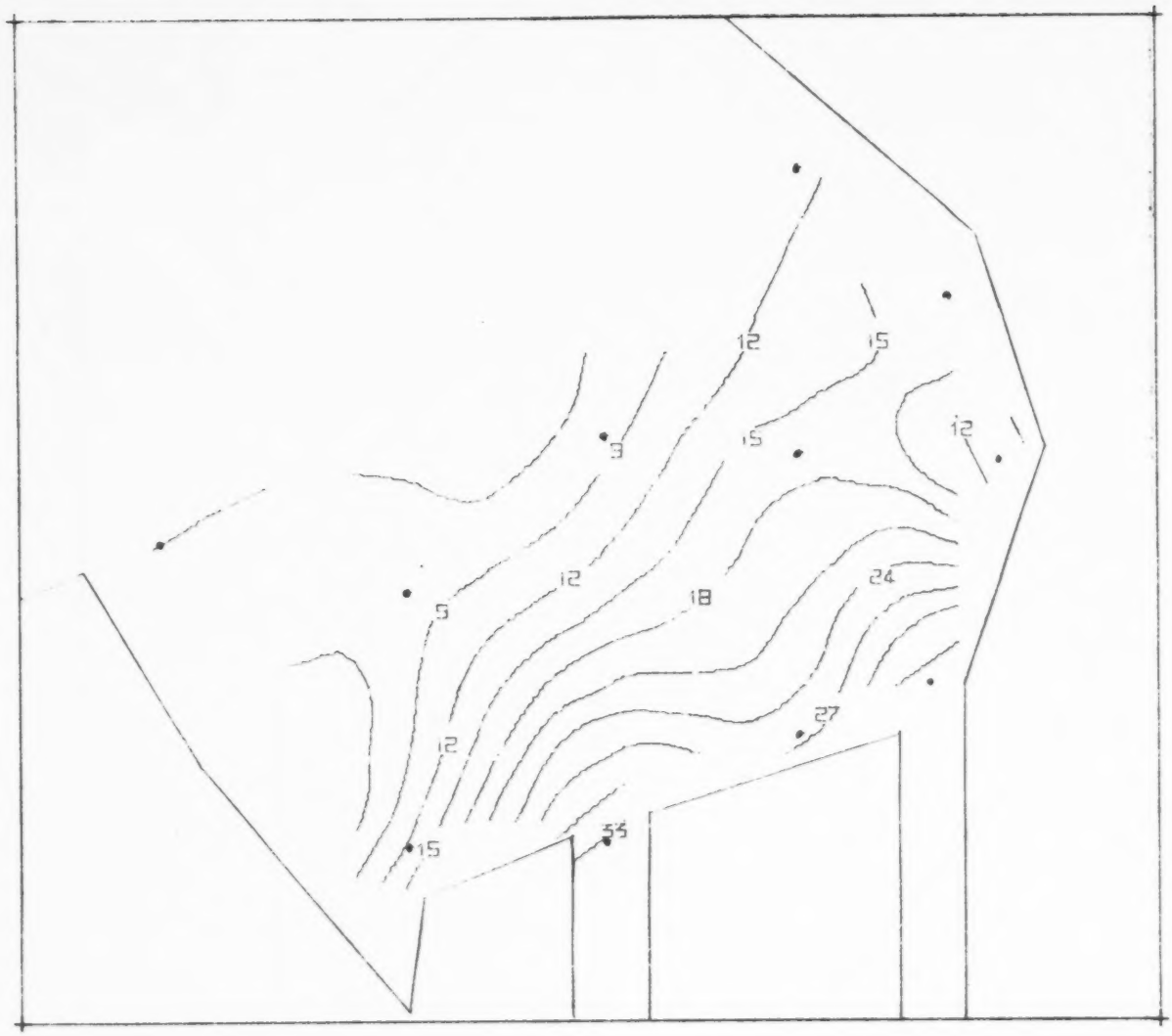


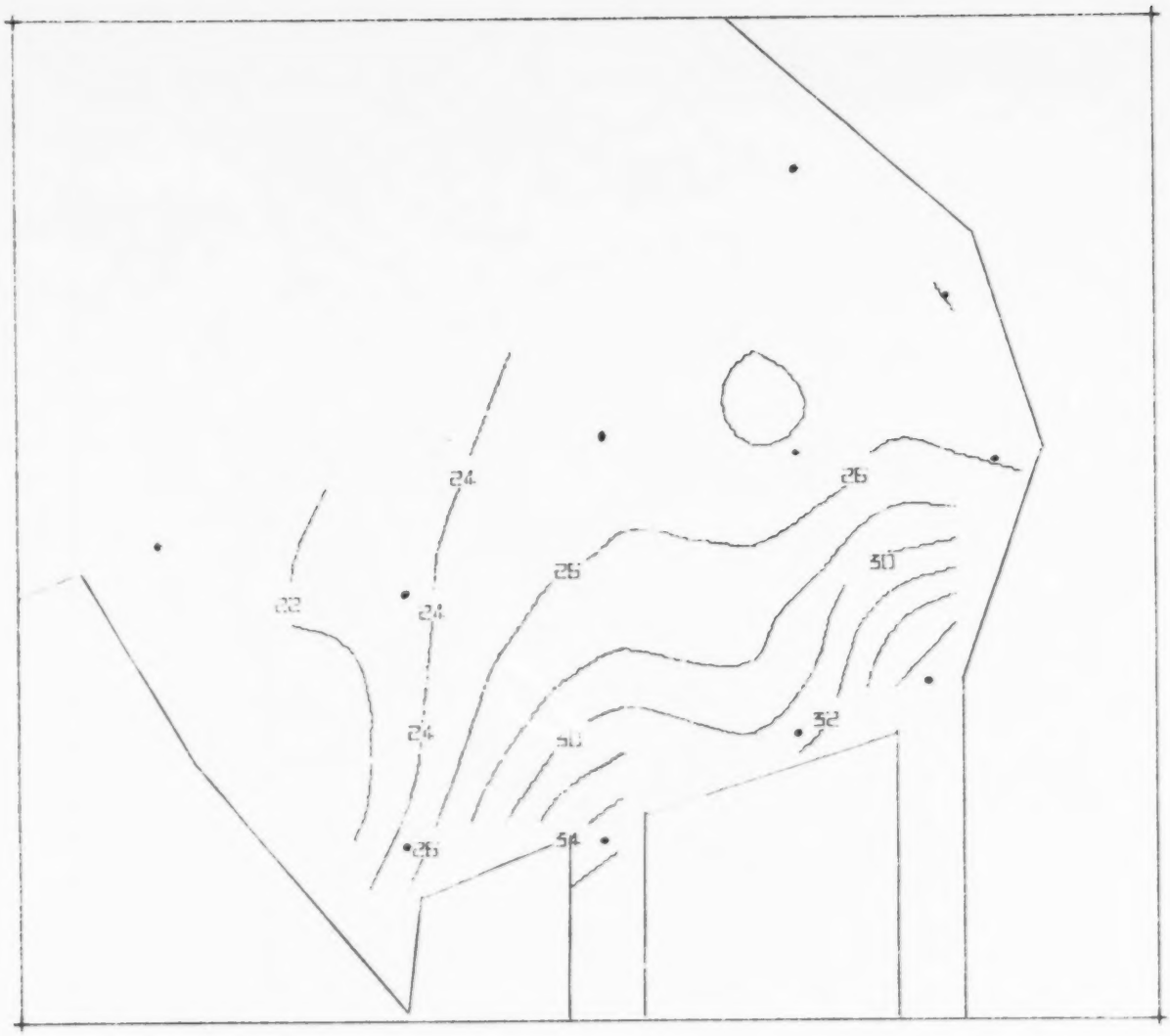
FIGURE 1 OXYGEN (COL ML AT/L OM



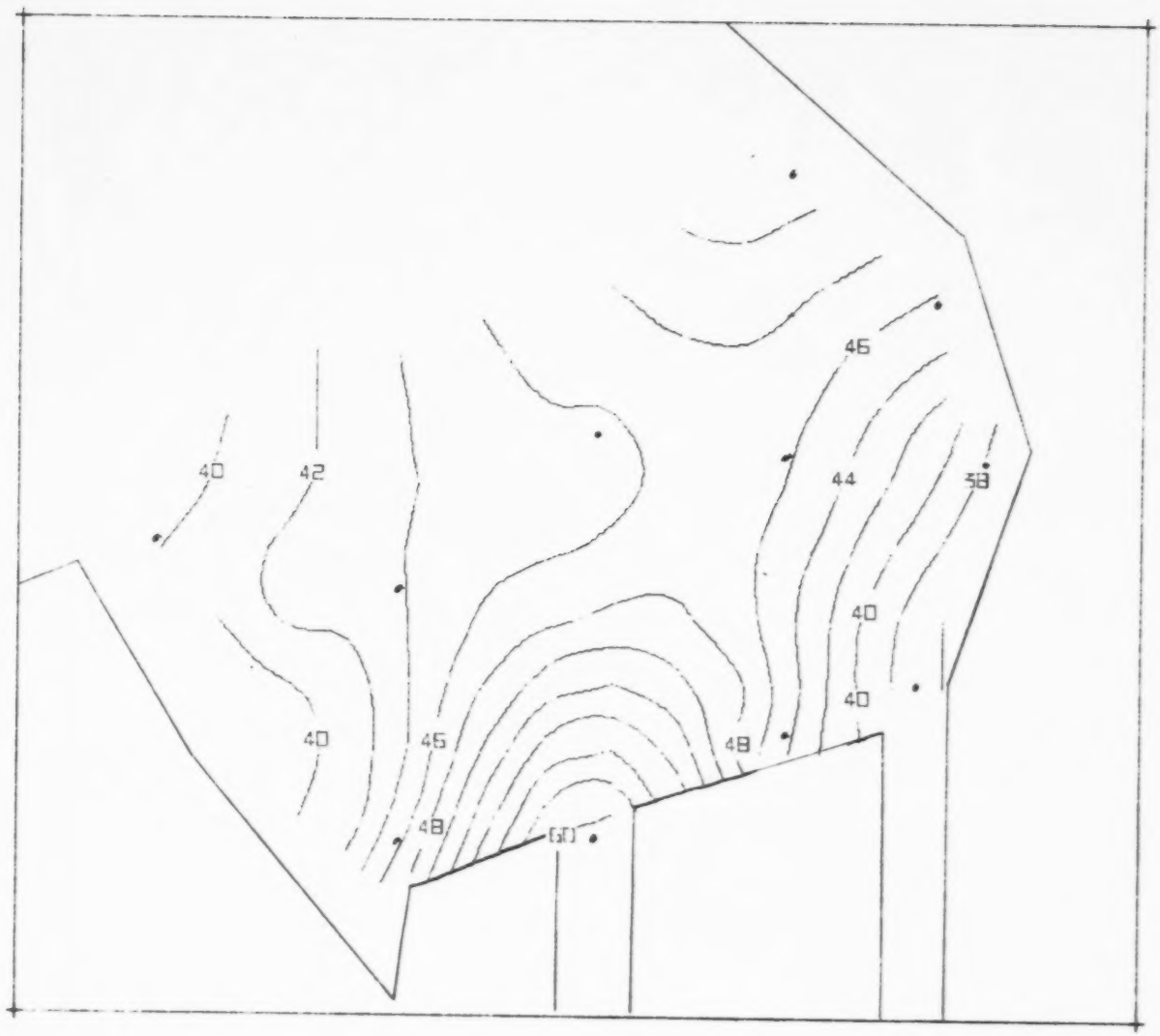
SYOPIS I NITRATE OM µG-AT/L



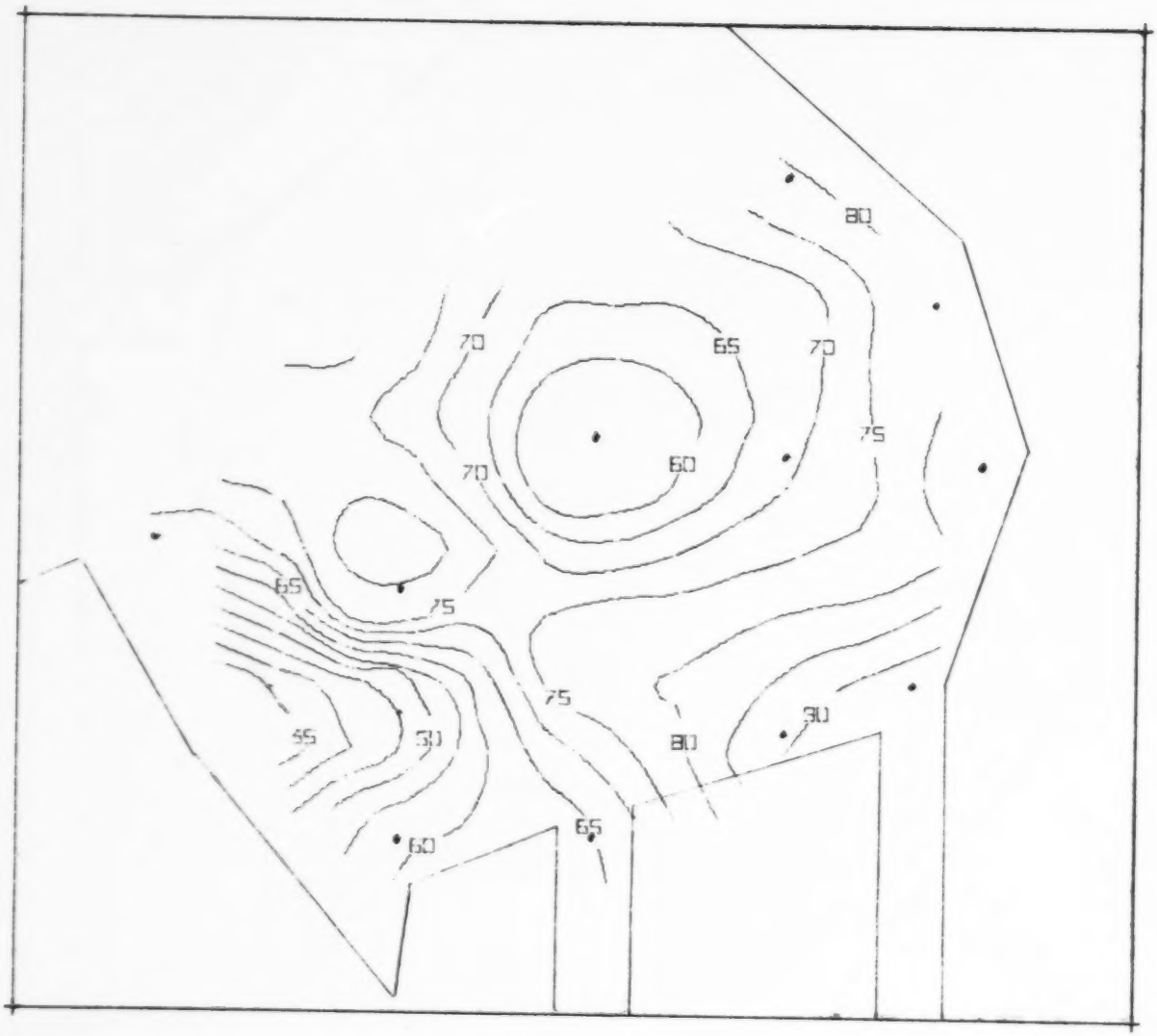
SYCRS T AMMONIA OM 0.1 µG-AT/L



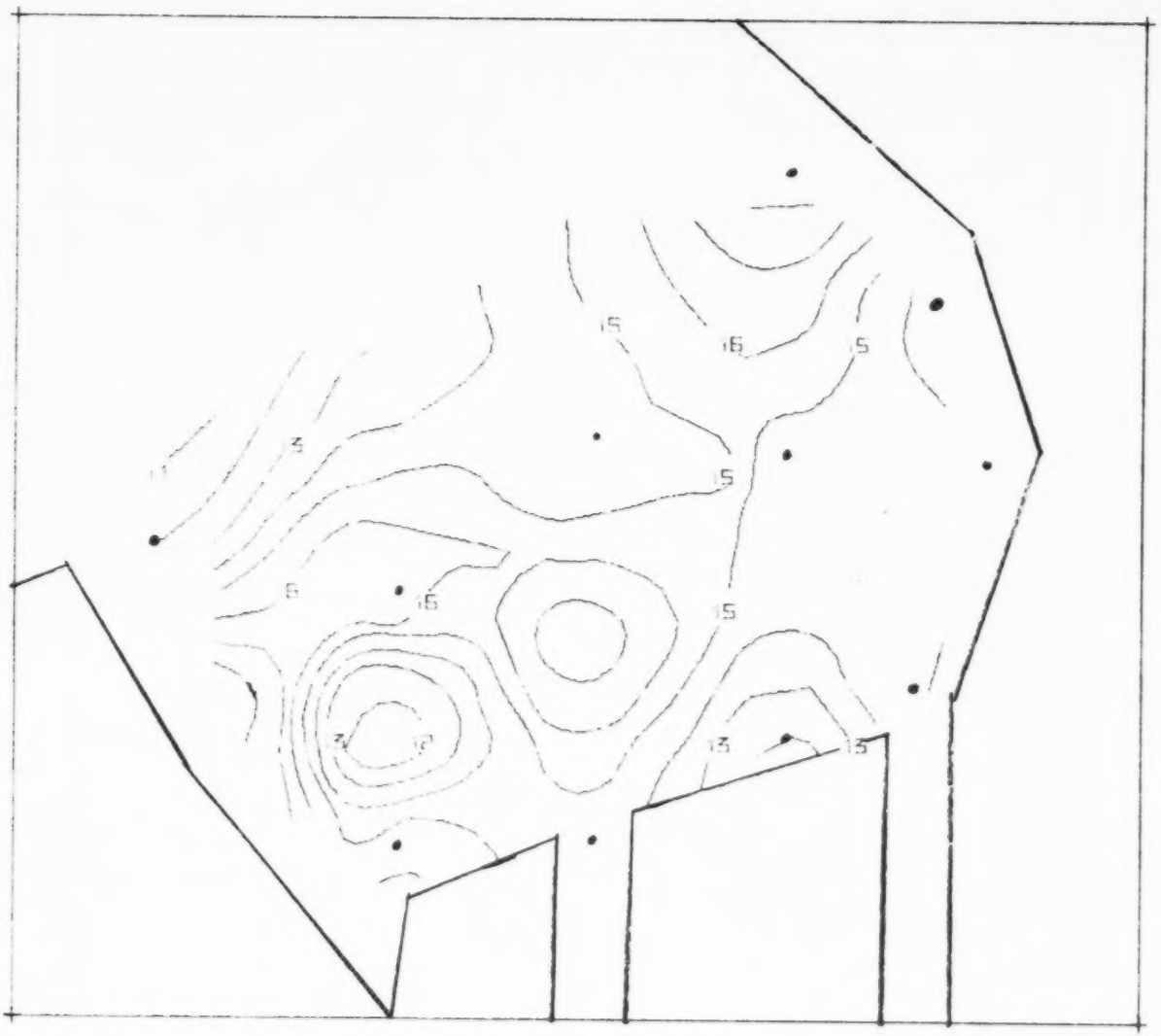
SYOPS I PHOSPHATE OM 0.1 µG-AT/L



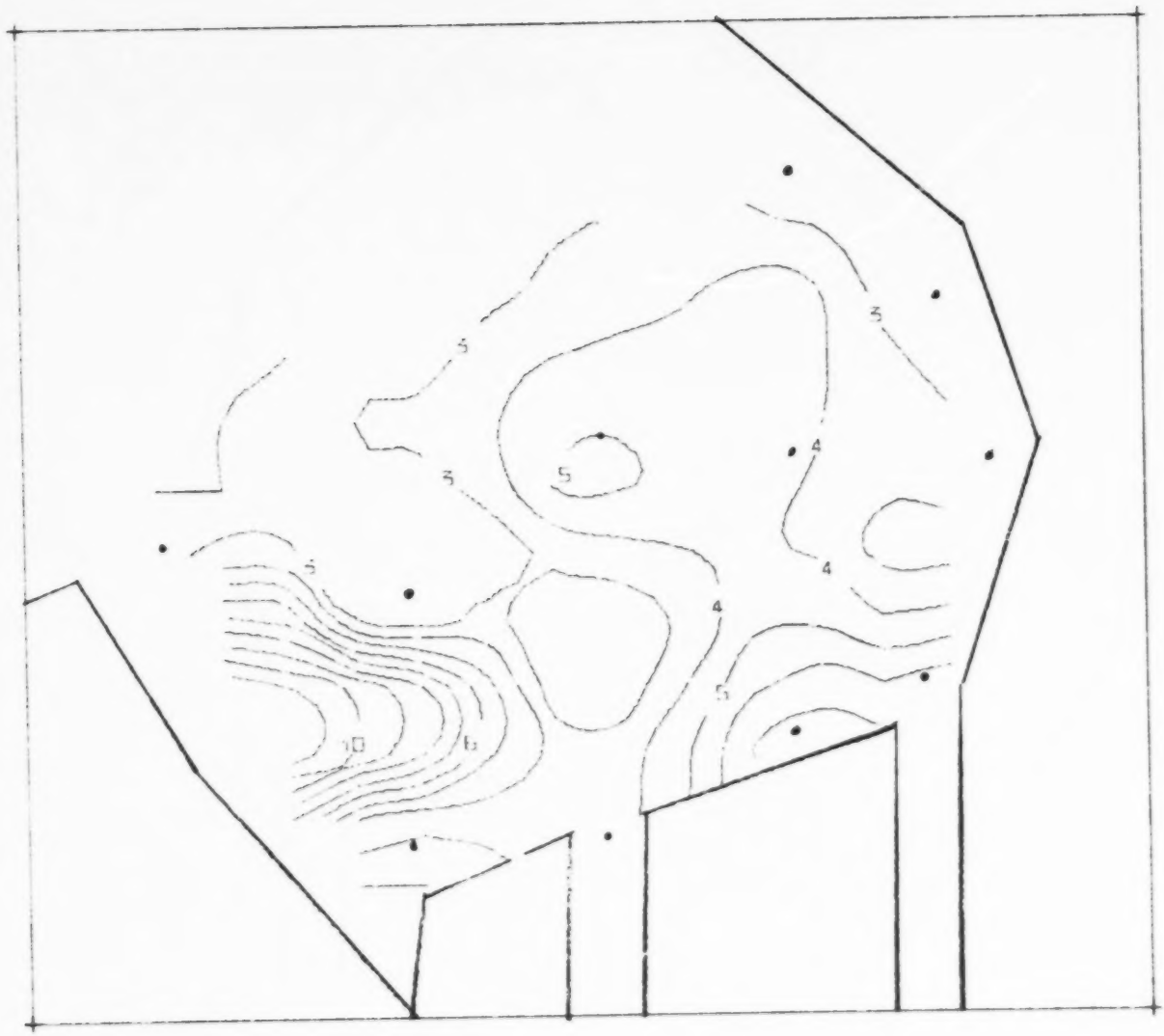
SYCRS 1 SILICATE 1 µG-AT/L OM



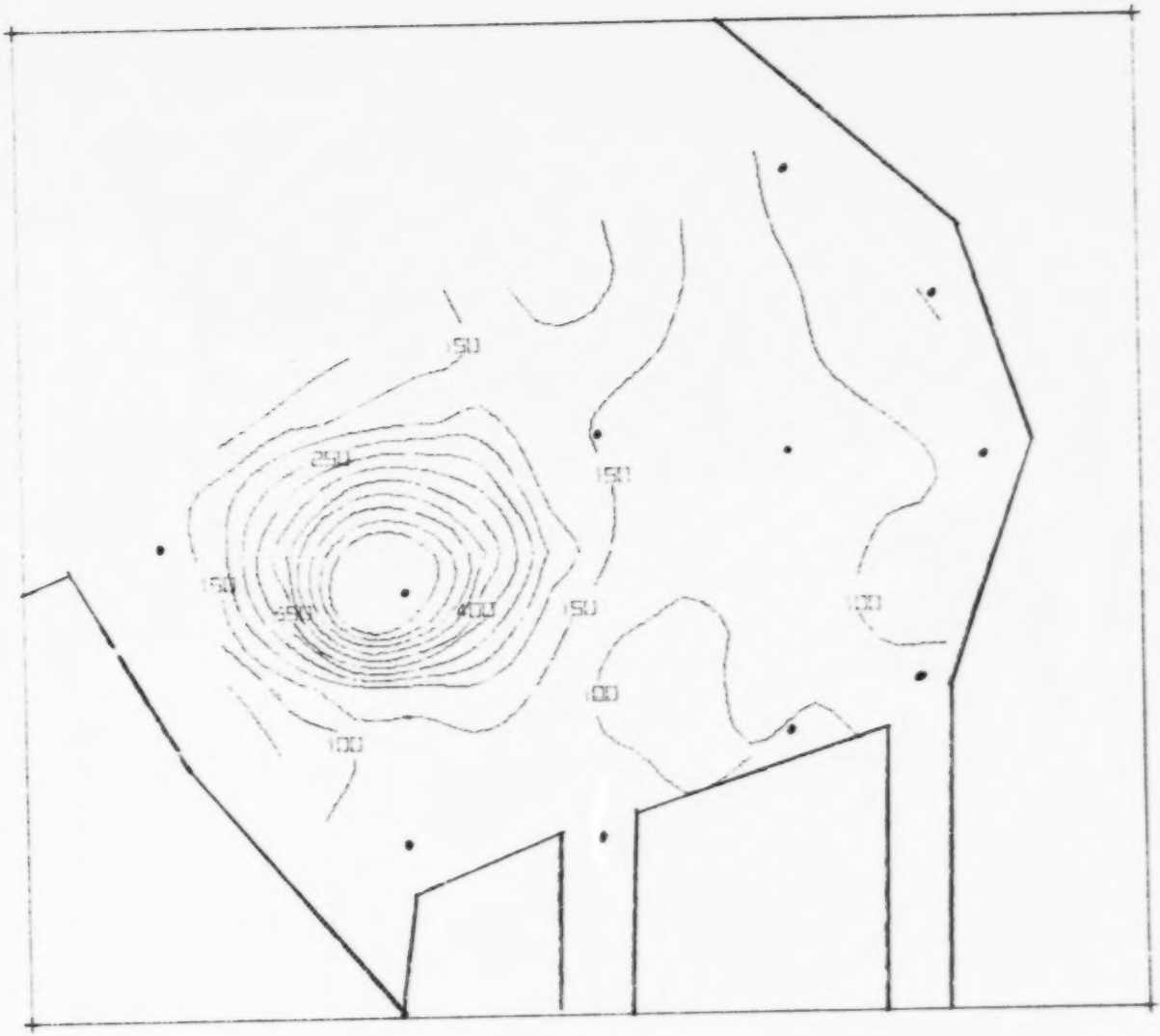
SYCAS I CHLOROPHYLL-A .01 MG/L OM



SYOPS I RN •J µG-AT/L OM

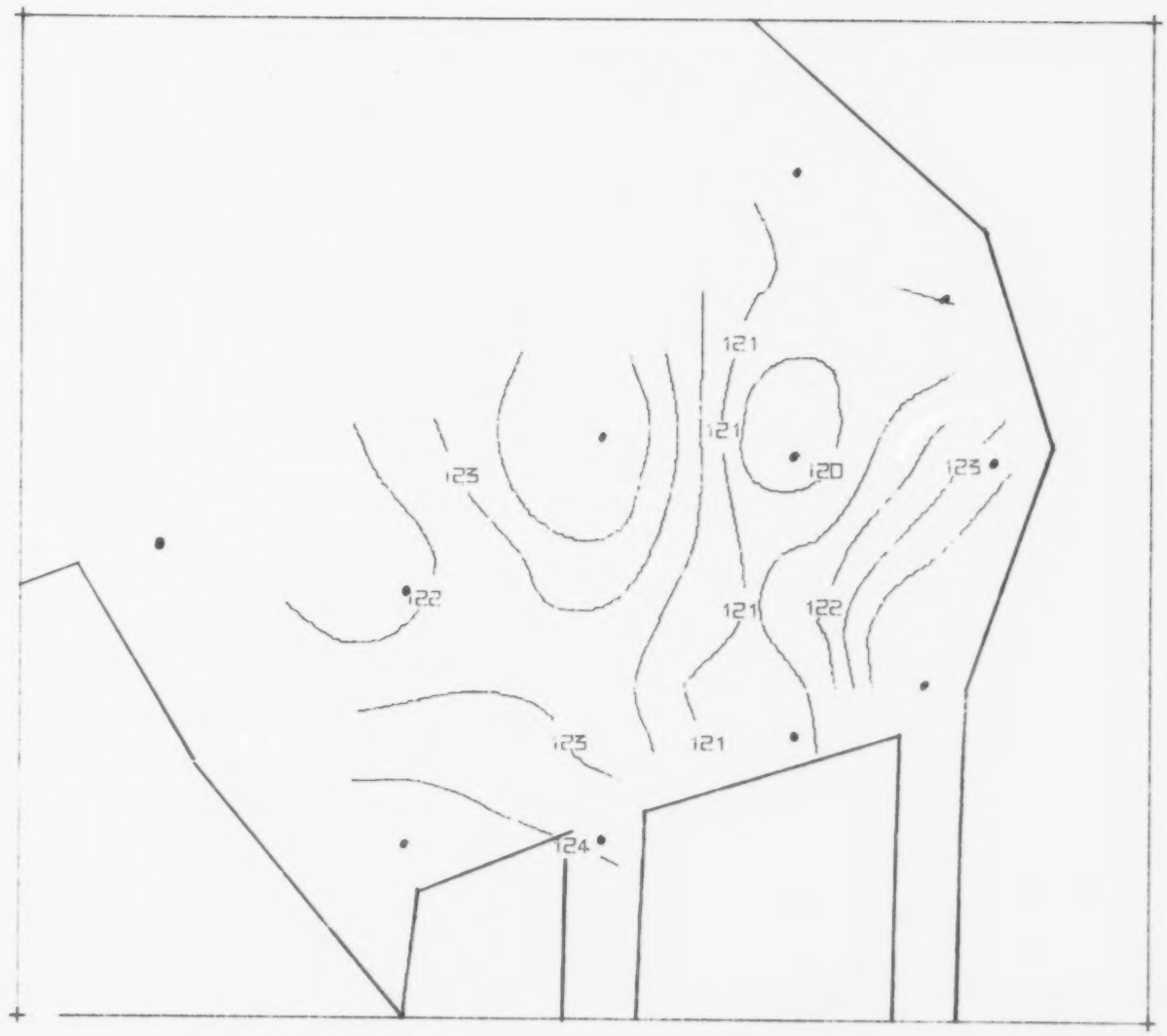


SYCHS I ETS .1 µL O2/L/HR OM

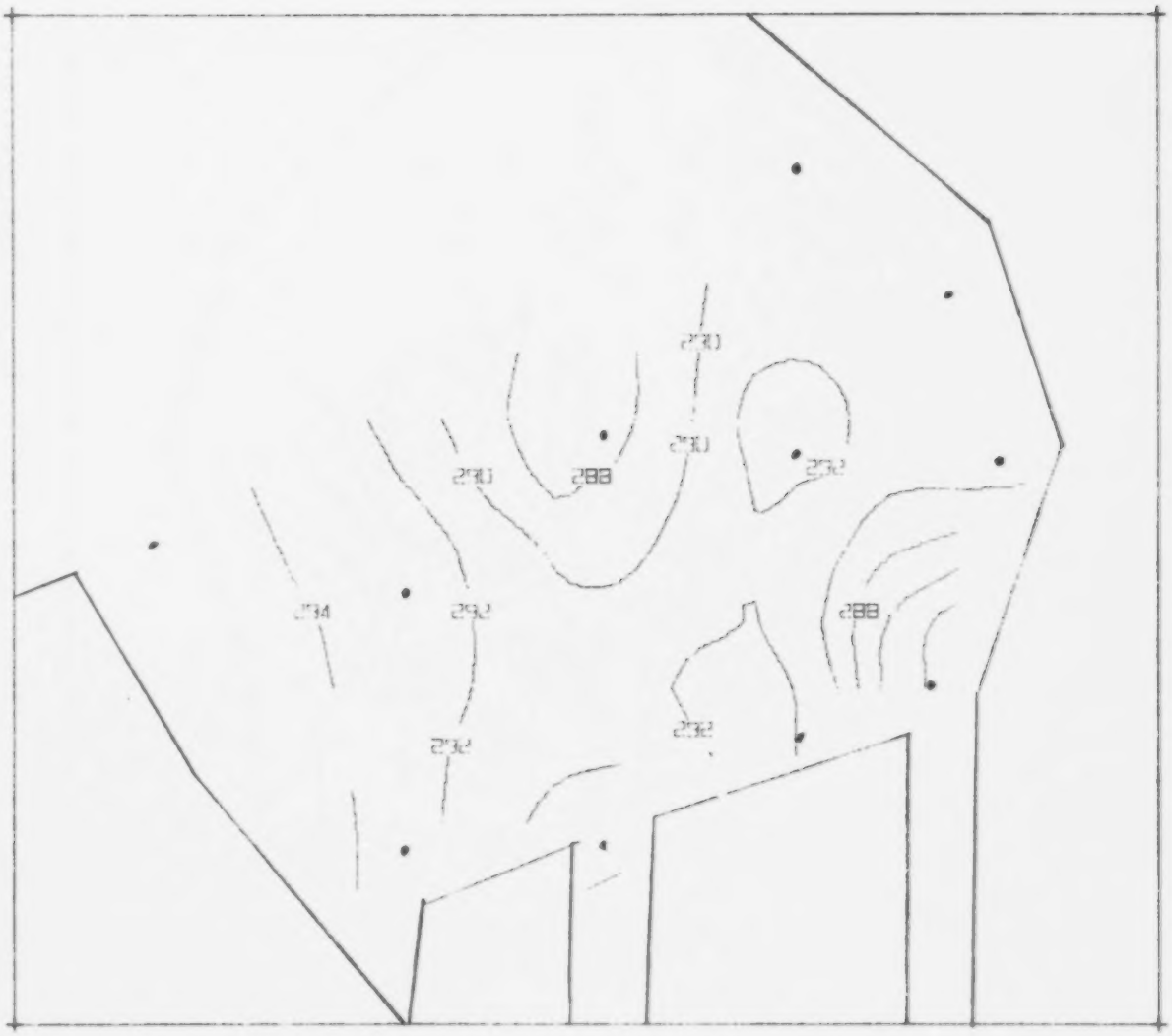


SYCP: I PROFILE IN X10-3 µG-ATM/L OM

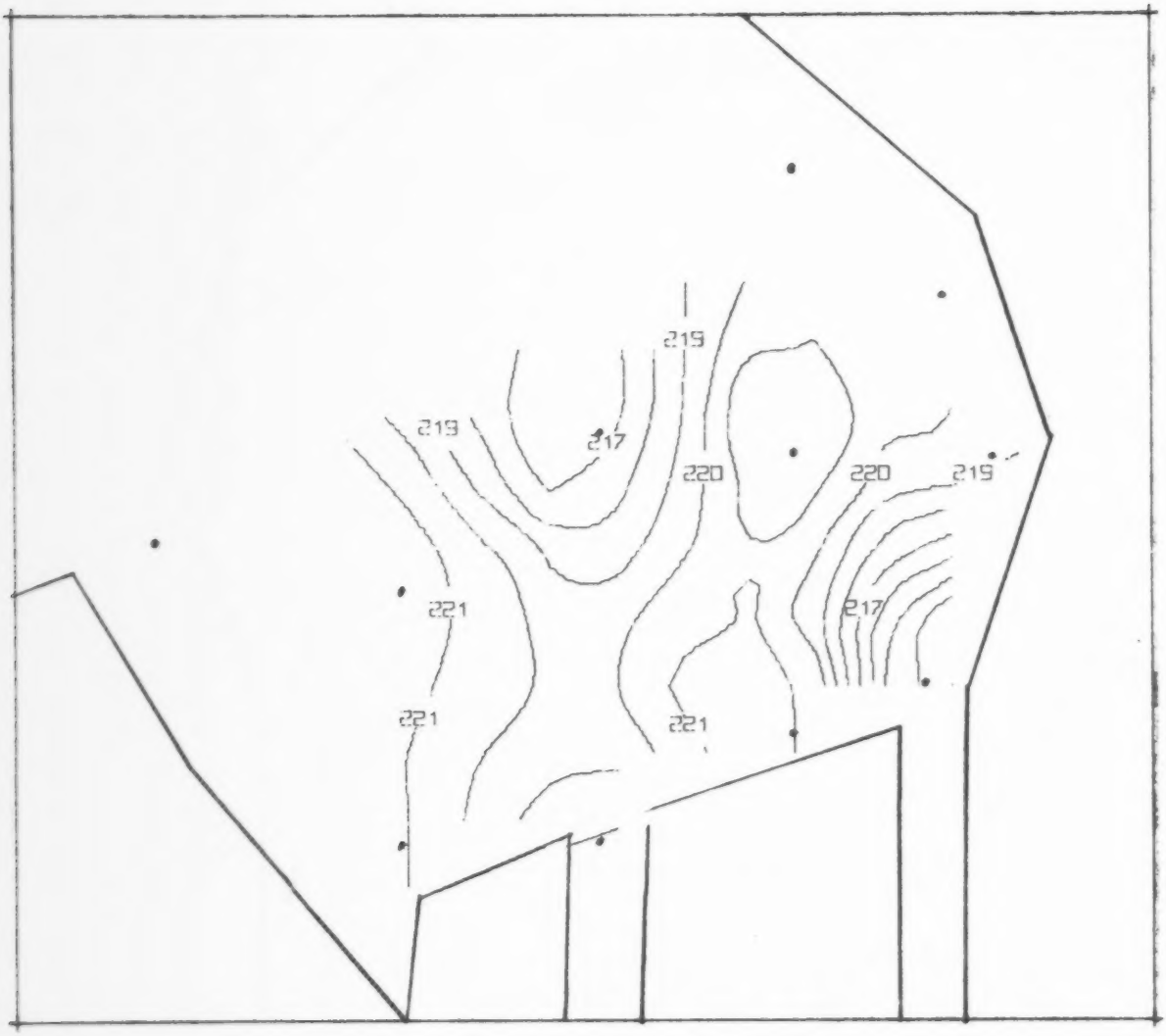
03 Meter Surface



CYCLE: 1 TEMPERATURE 03M .1 DEGREE C



SYDNEY HARBOUR SALINITY 0730M PPM



SYOPS I SIGMA-T OBM .I SIGMA-T UNIT

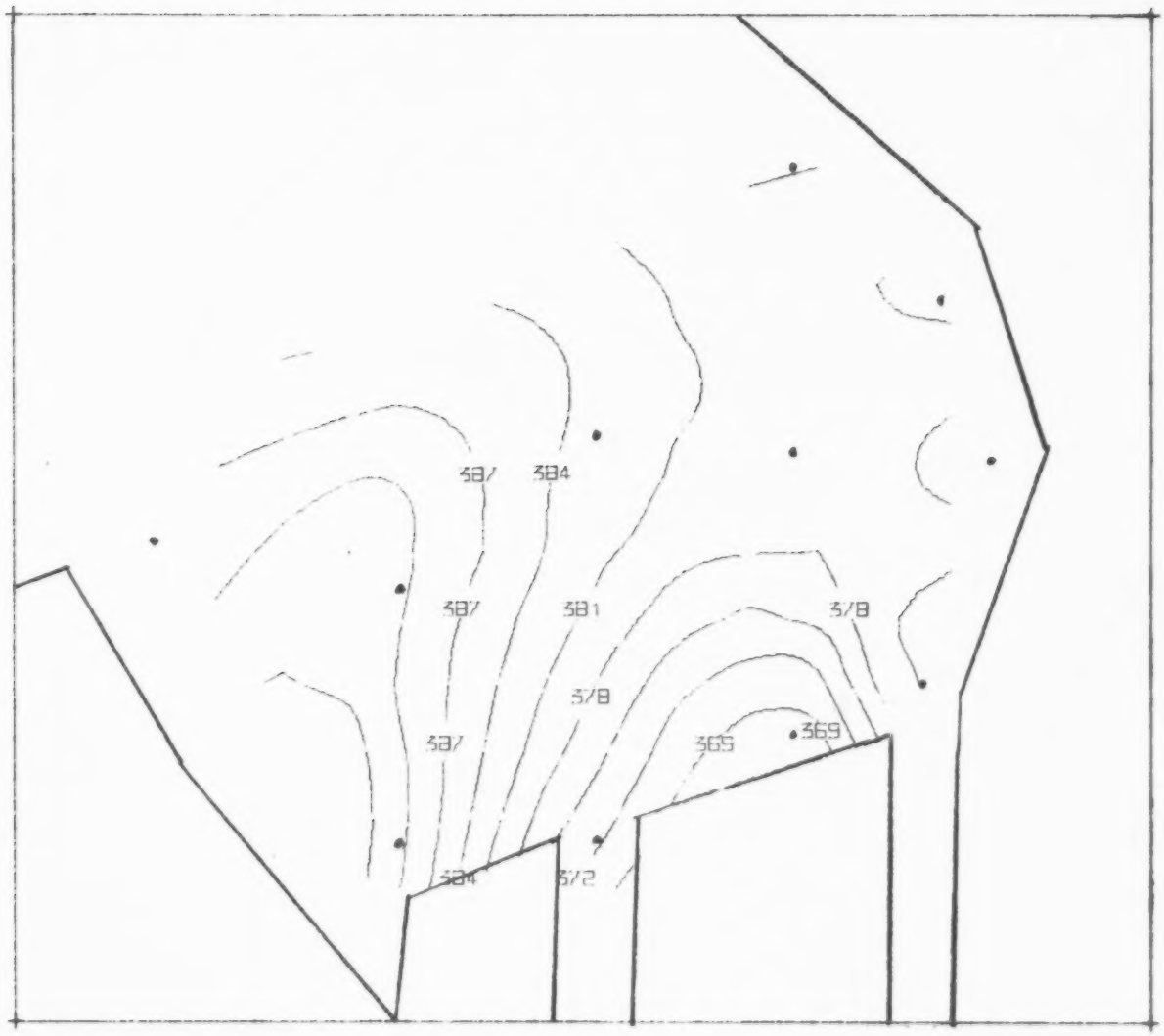
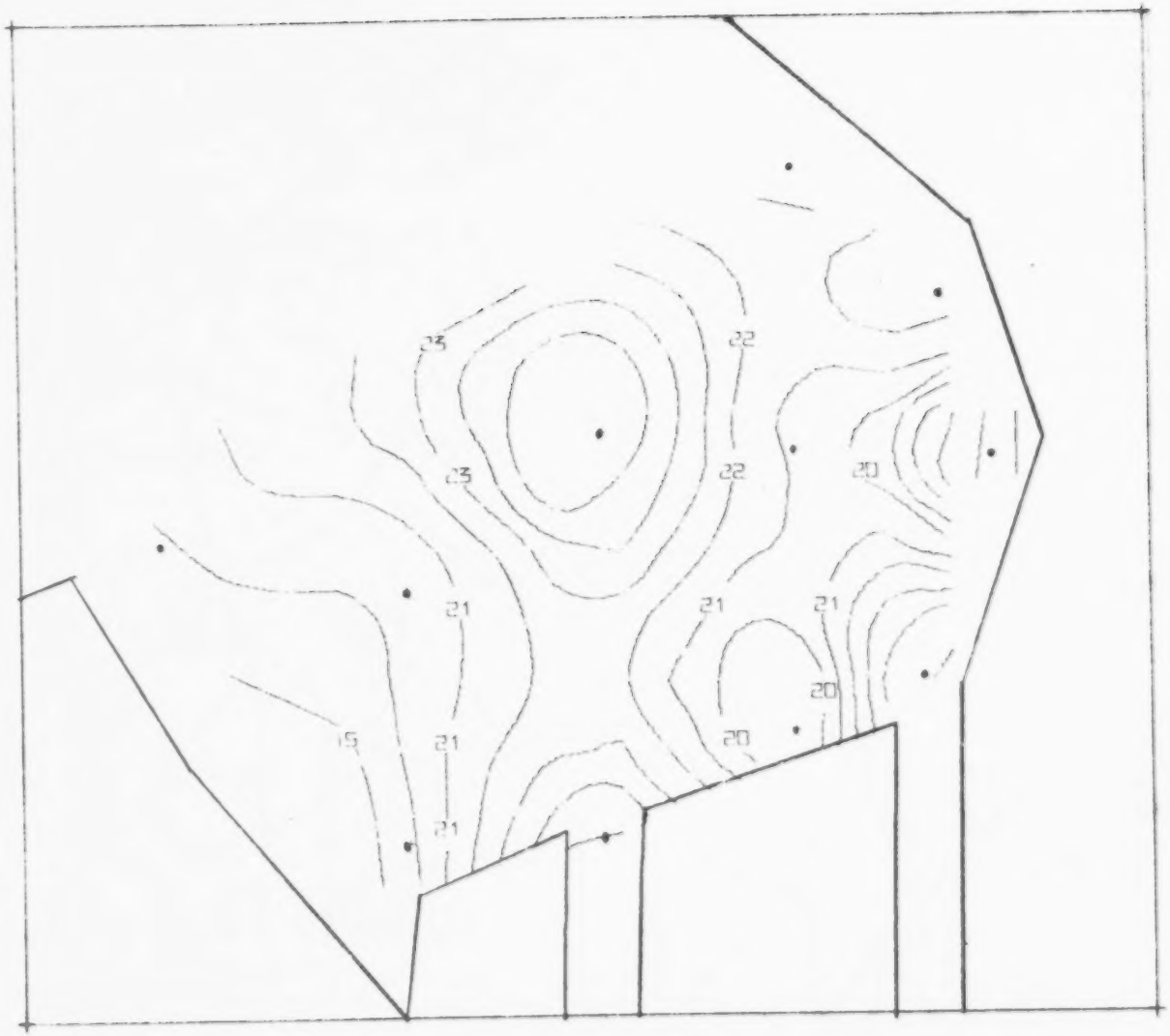
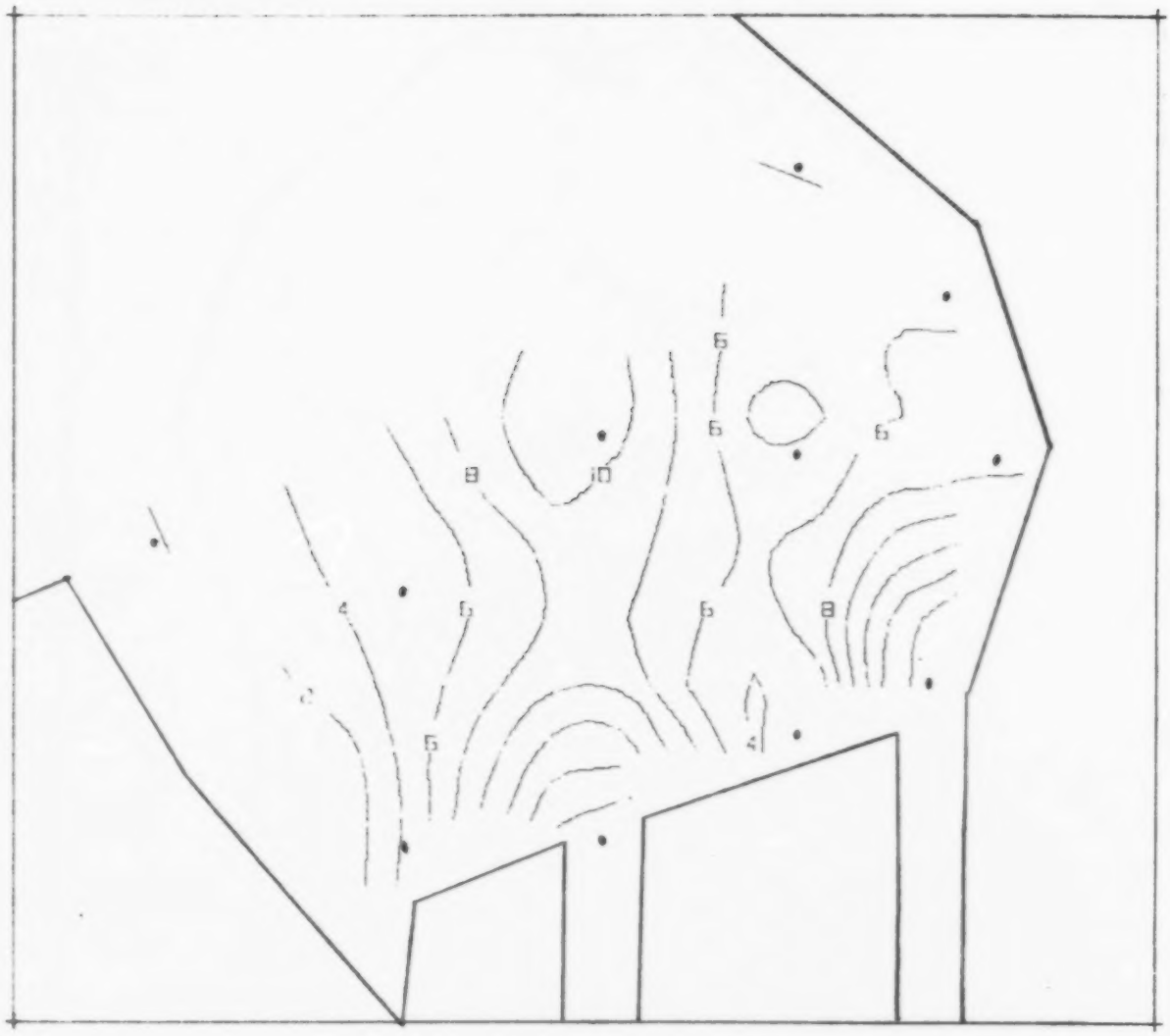


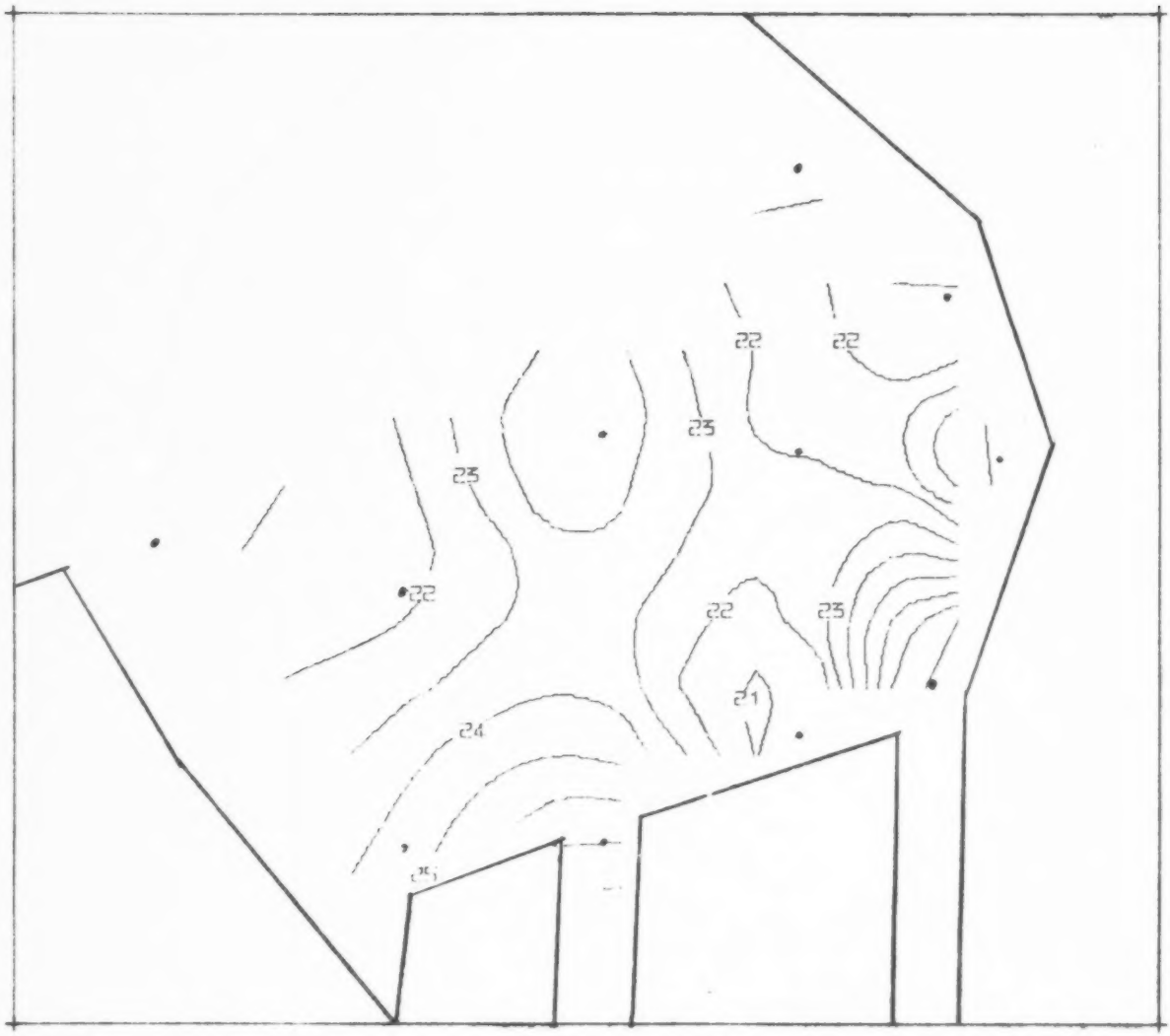
FIGURE 1 OXYGEN .001 MG AT/L 03M



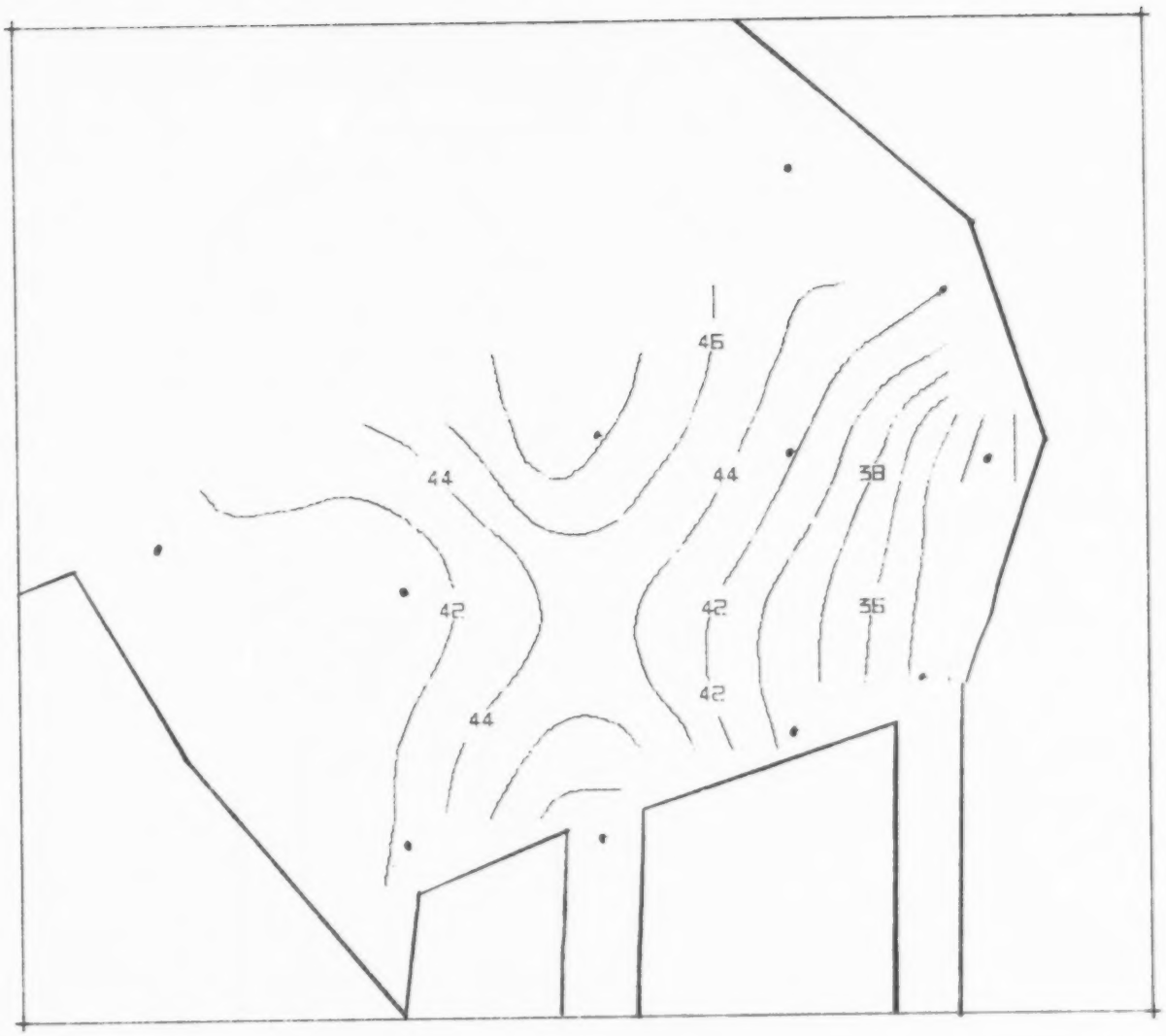
SYOPS I NITRATE 1/UG-AT/L 03M



[illegible] AMMONIA 0.3M .1 UG-AT/L

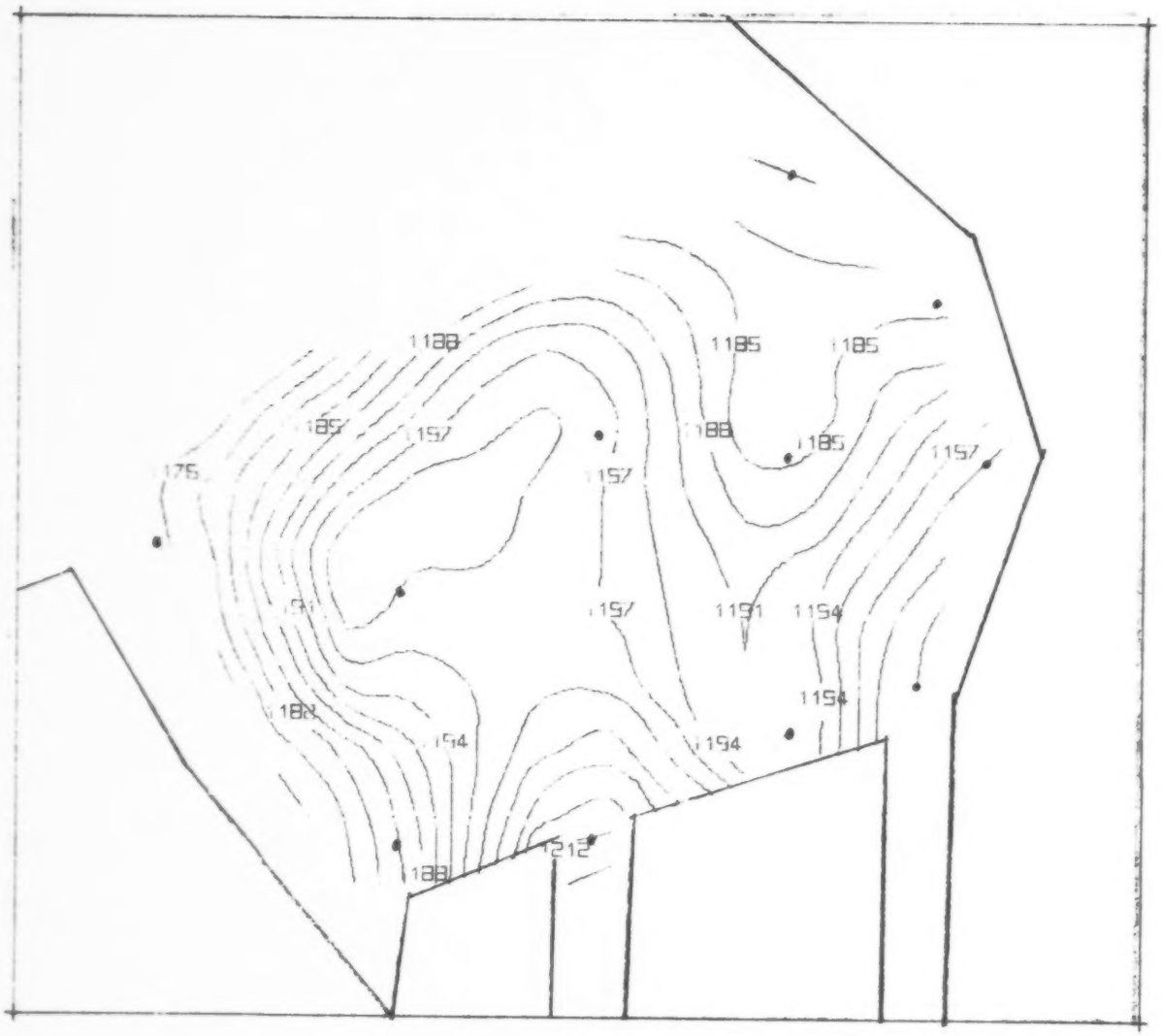


SYOPS I PHOSPHATE 03M .! UG-AT/L

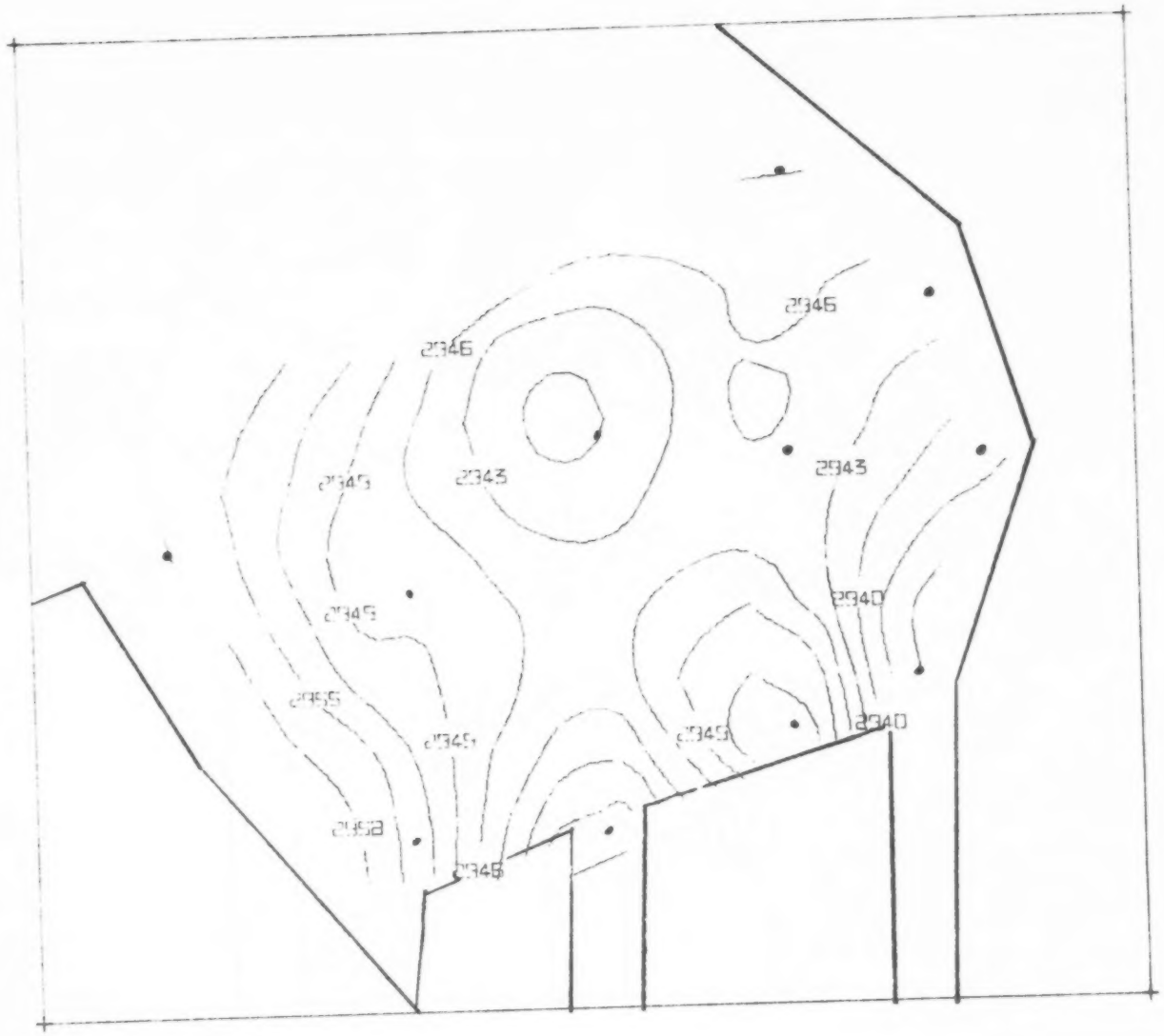


SYCPS I SILICATE OBM 1 µG-AT/L

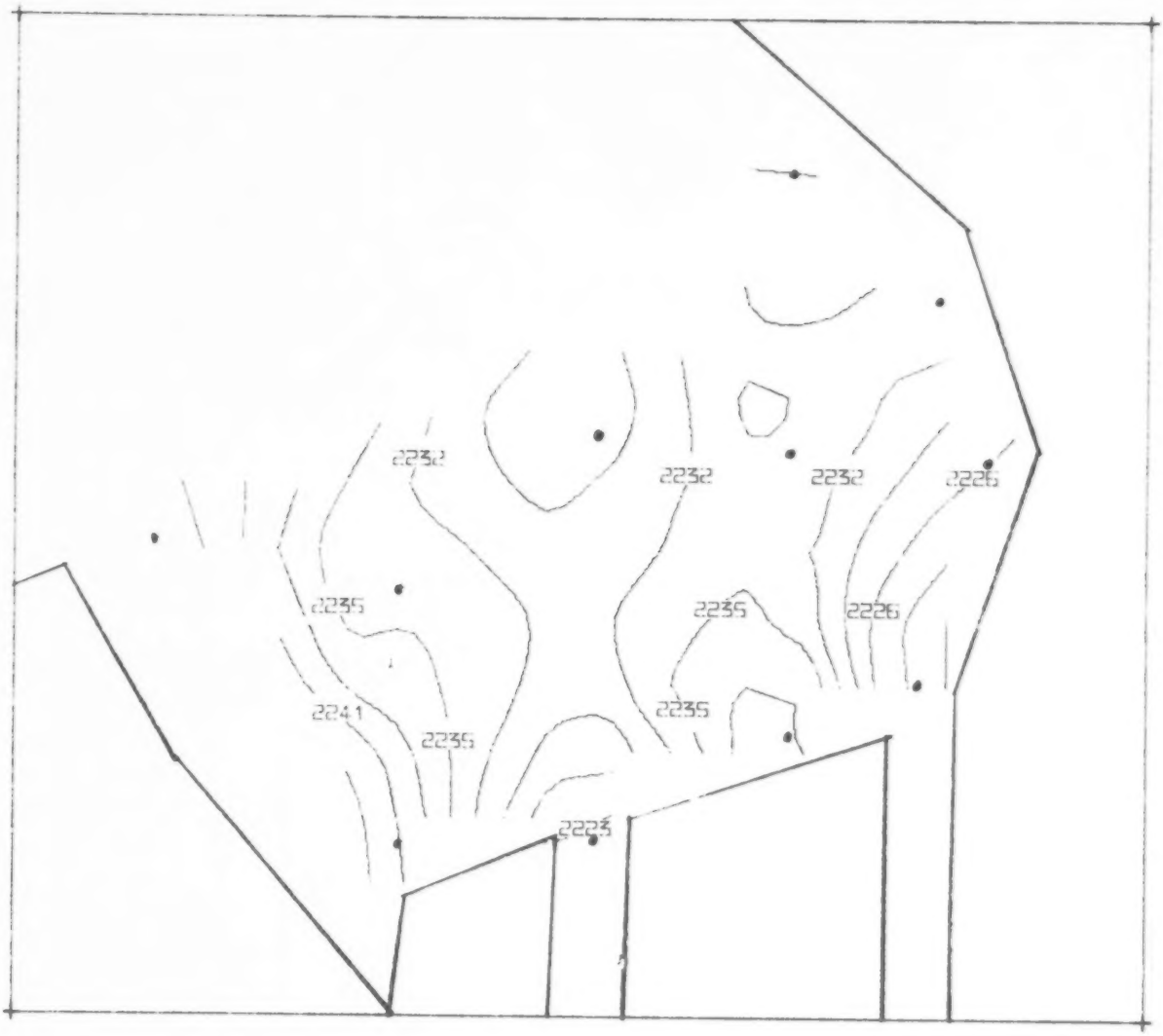
06 Meter Surface



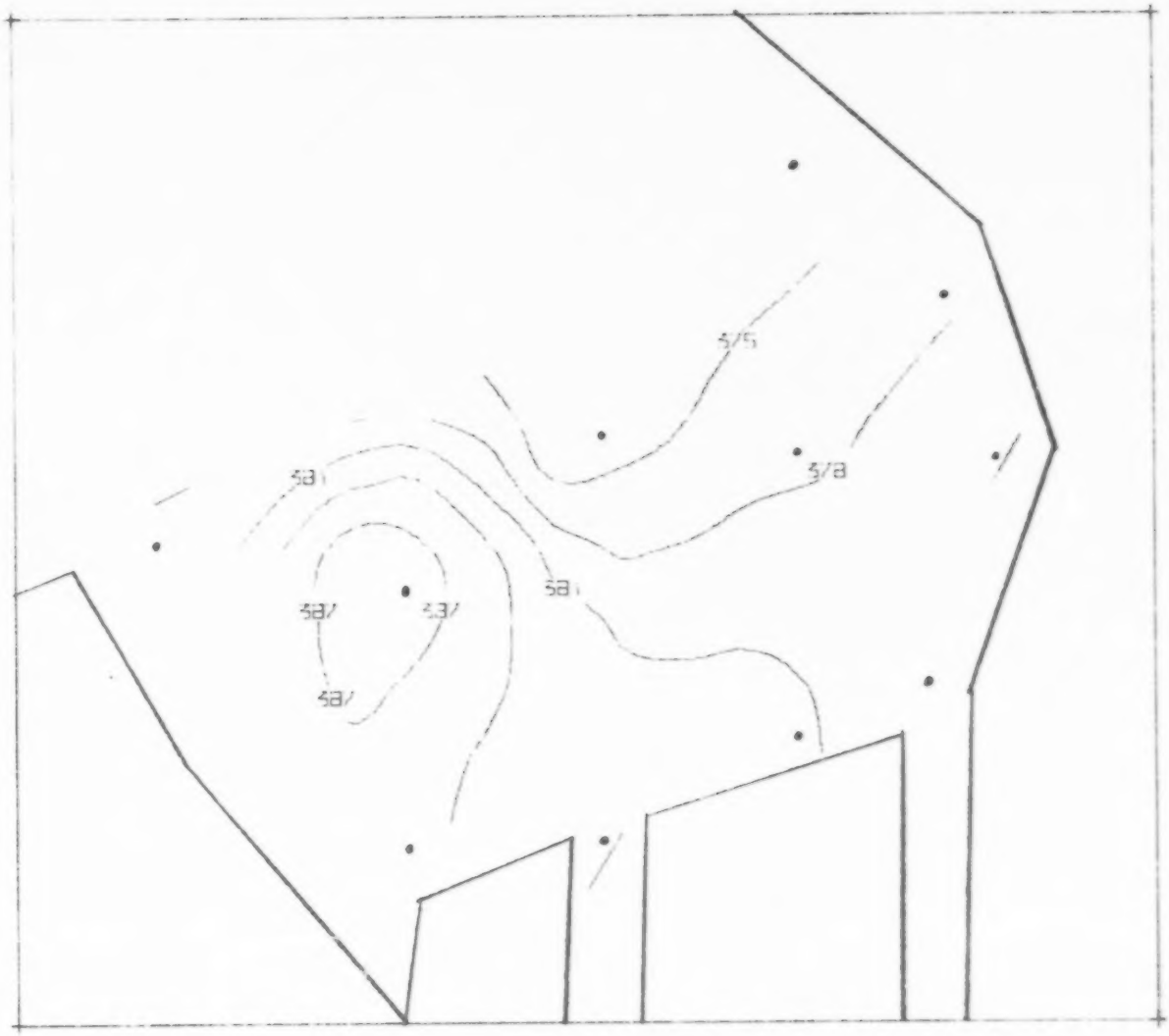
SYOPS I TEMPERATURE .01 DEGREE C 06M



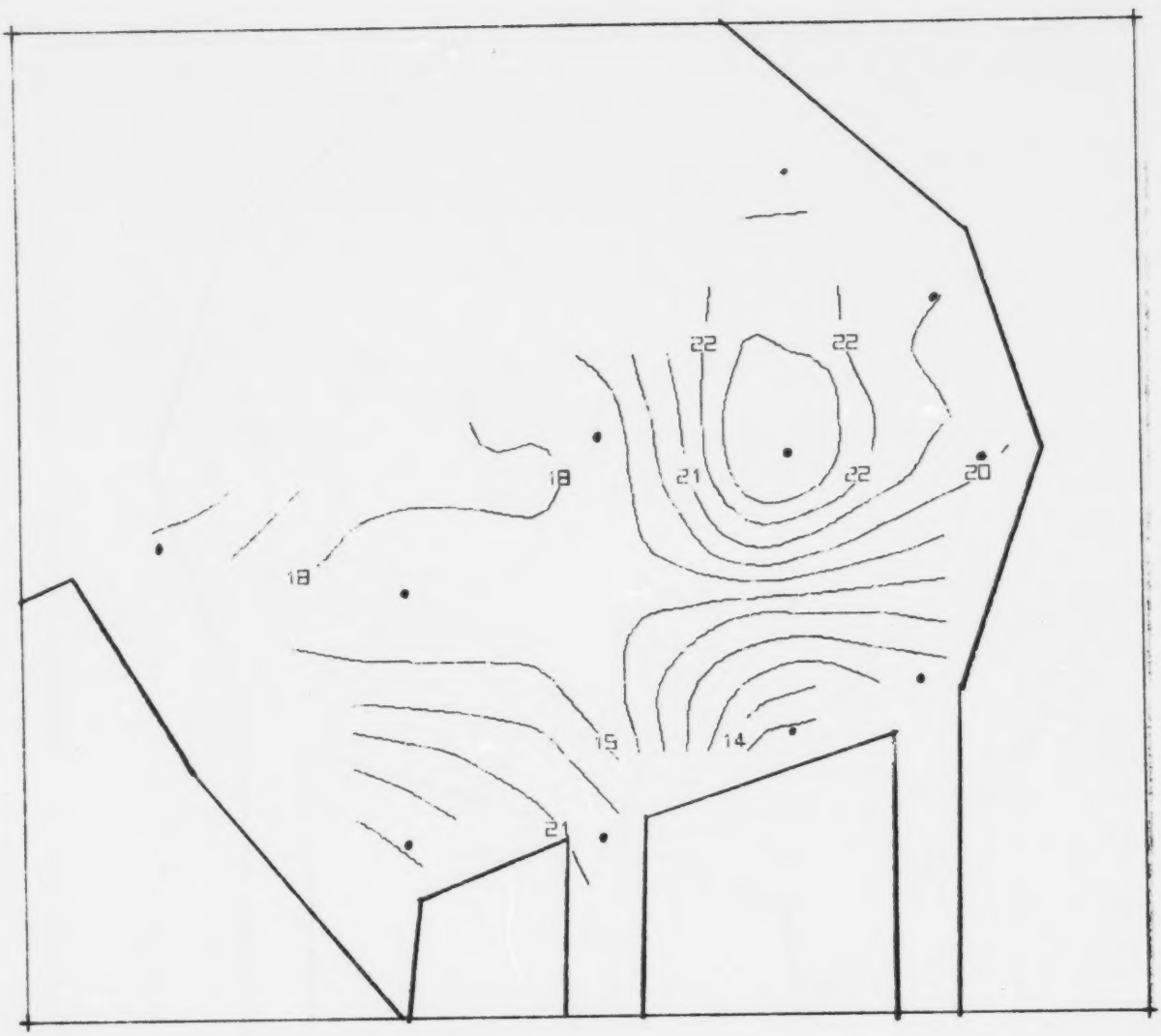
SYOPS I SALINITY PPM 06M



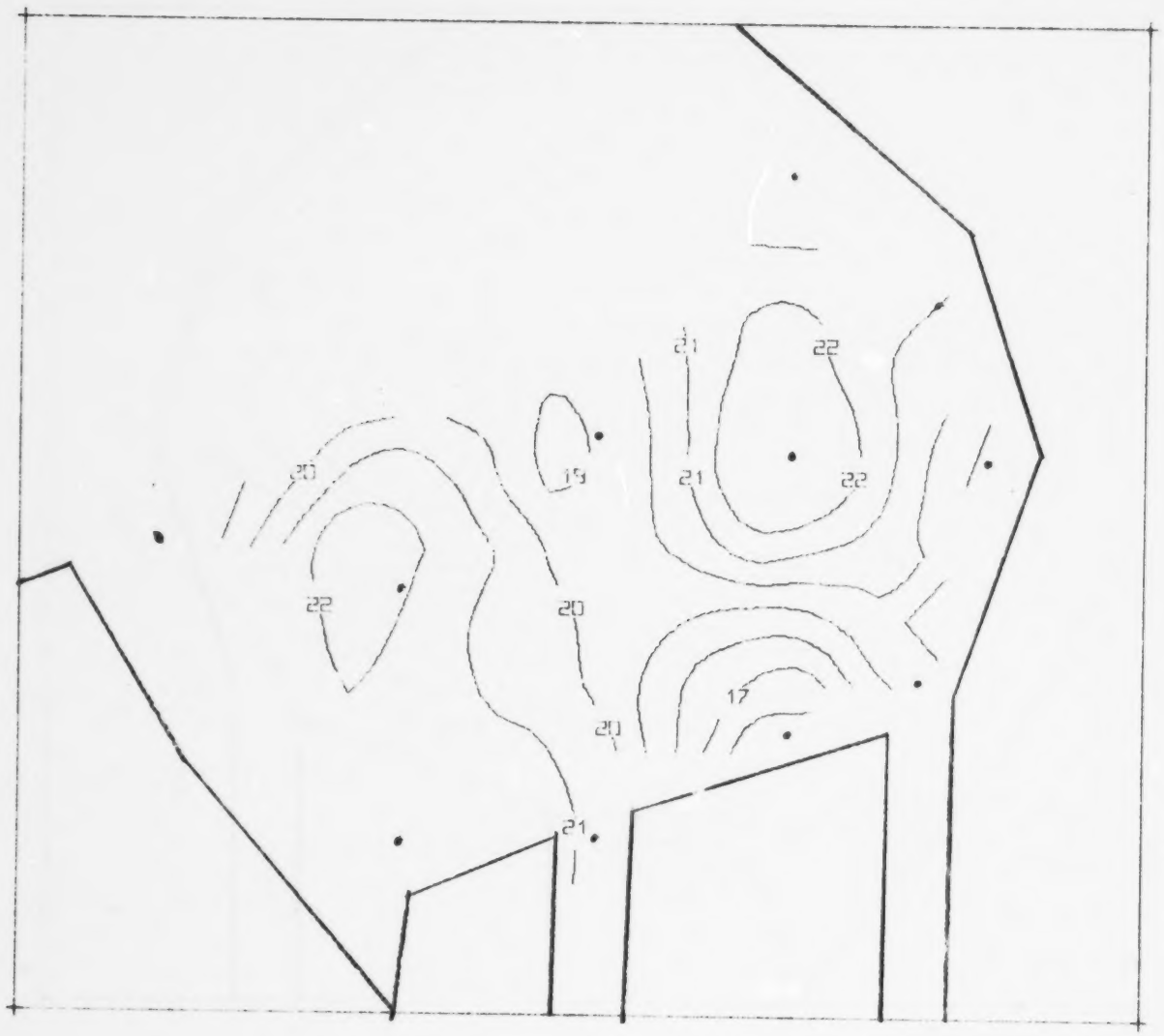
SYSTEMATIC SYSTEMATIC UNIT 01SM



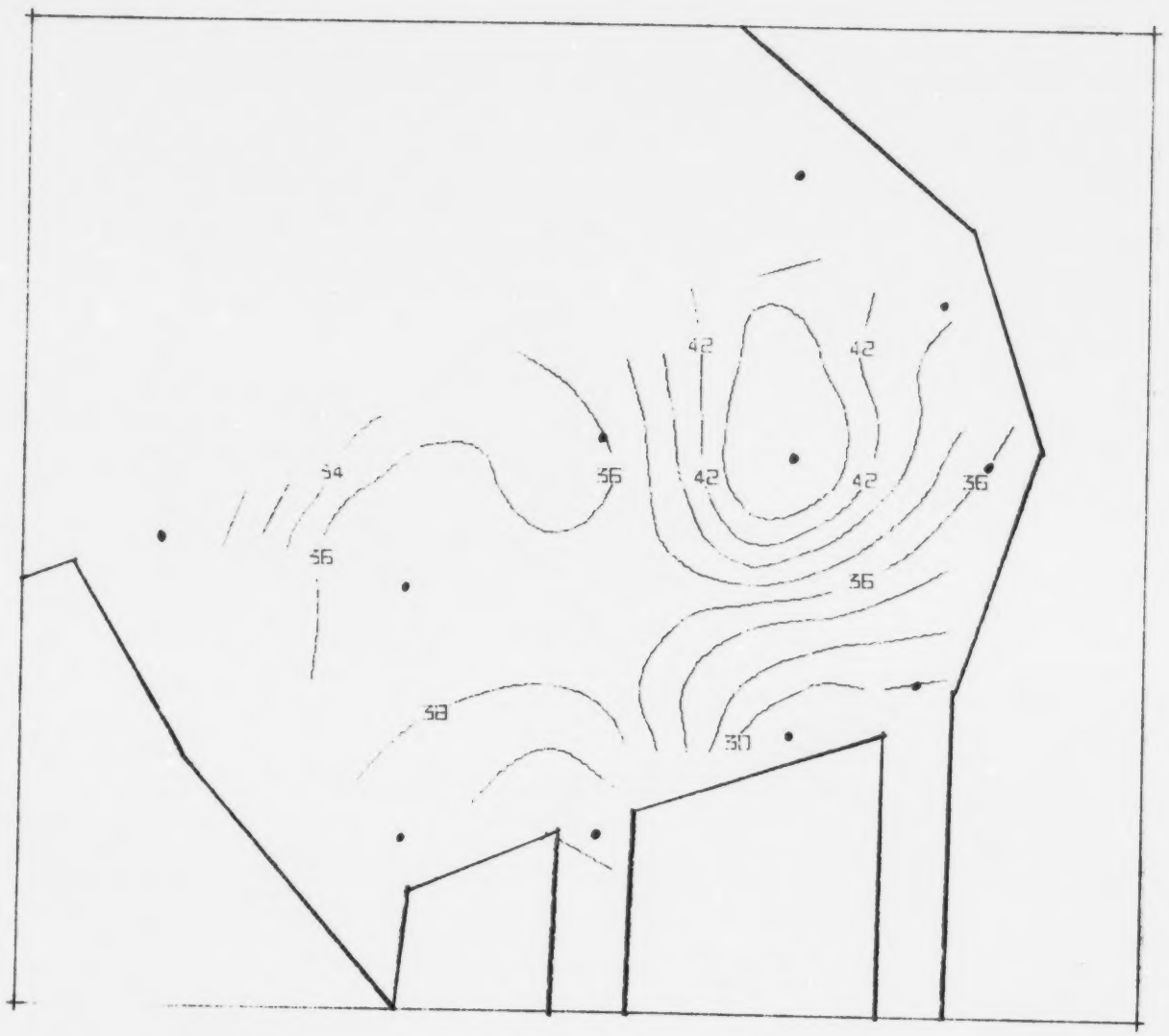
SYSTEM 1 OXYGEN -001 MG AT/L 06M



SYOPS I NITRATE 1 µG-AT/L 06M



SYCAMORE PHOSPHATE - 1 JUG AT 4L 06M

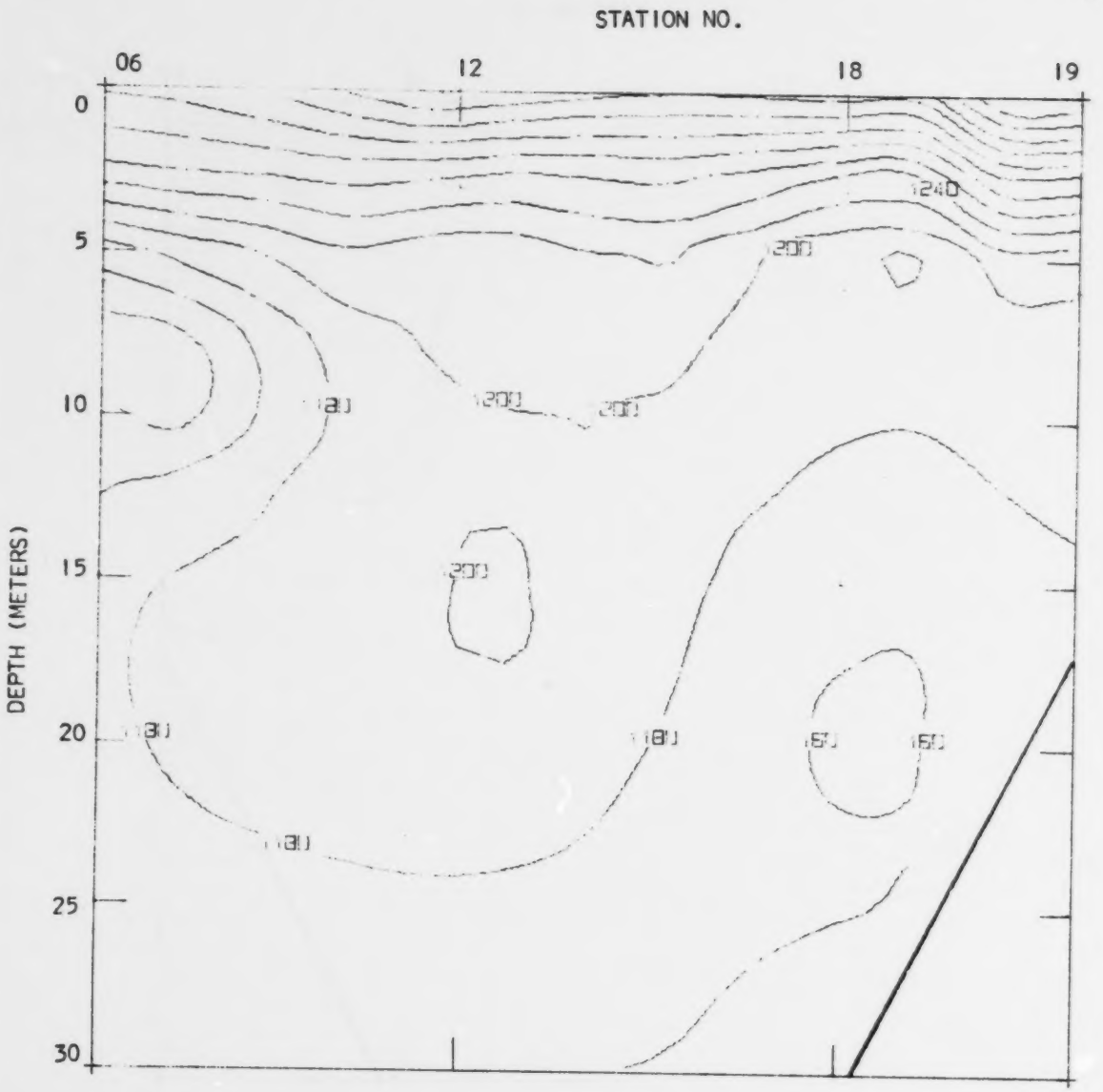


SYOPS 1 SILICATE 1 μG-AT/L 06M

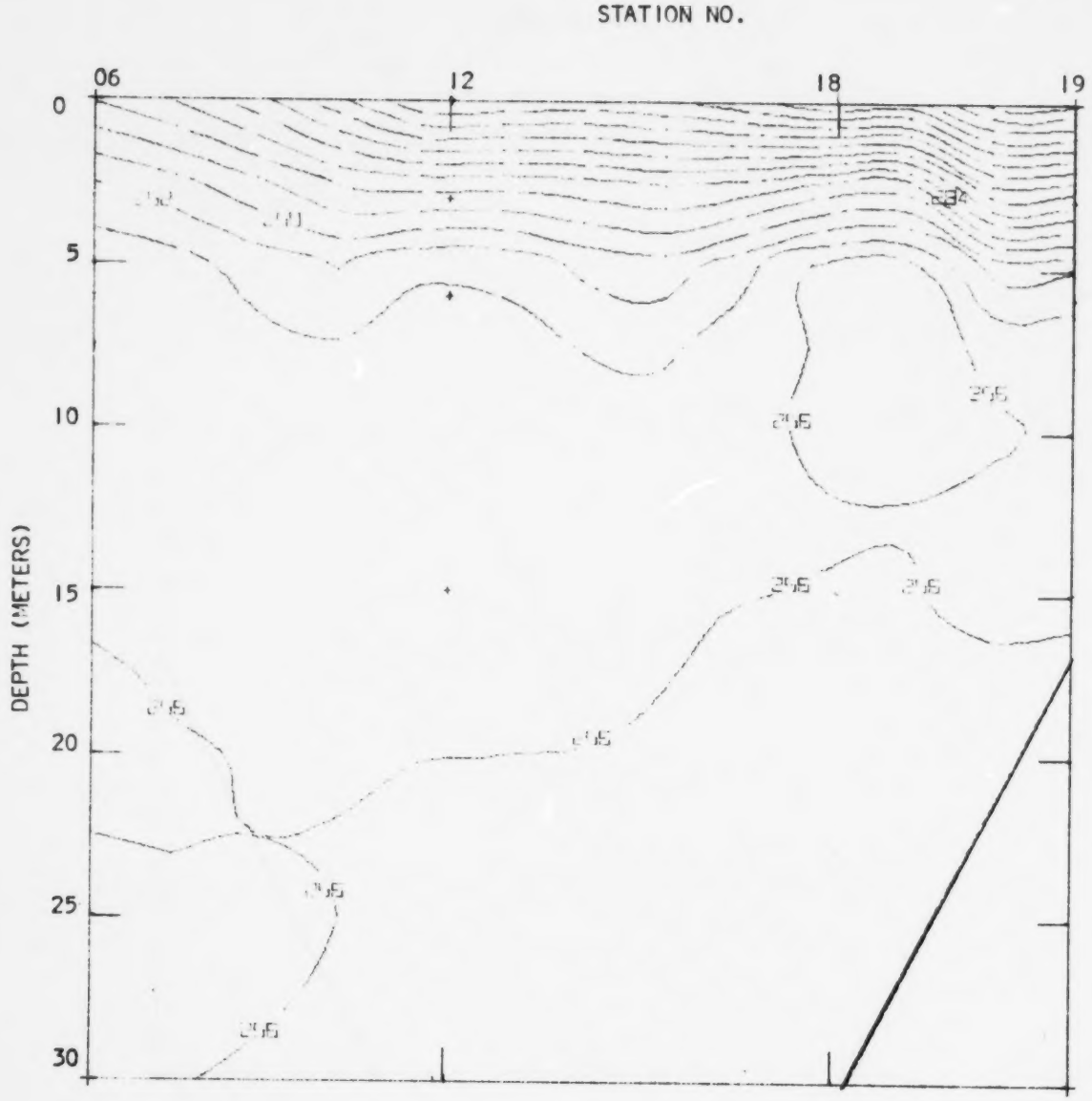
VERTICAL CONTOUR PLOTS (SYOPS-I)

Station 06-12-18-19 transect

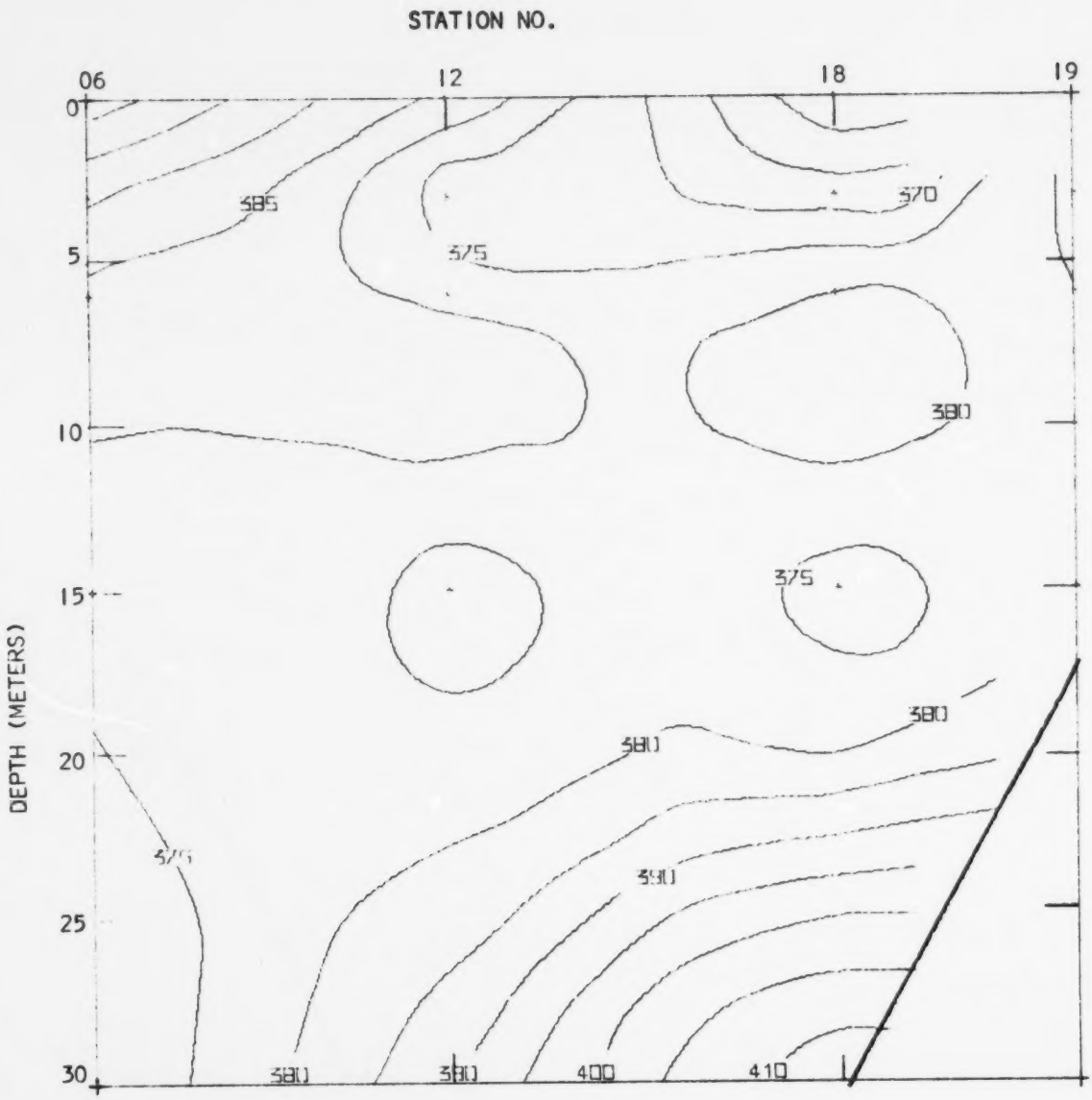
Preceding page blank



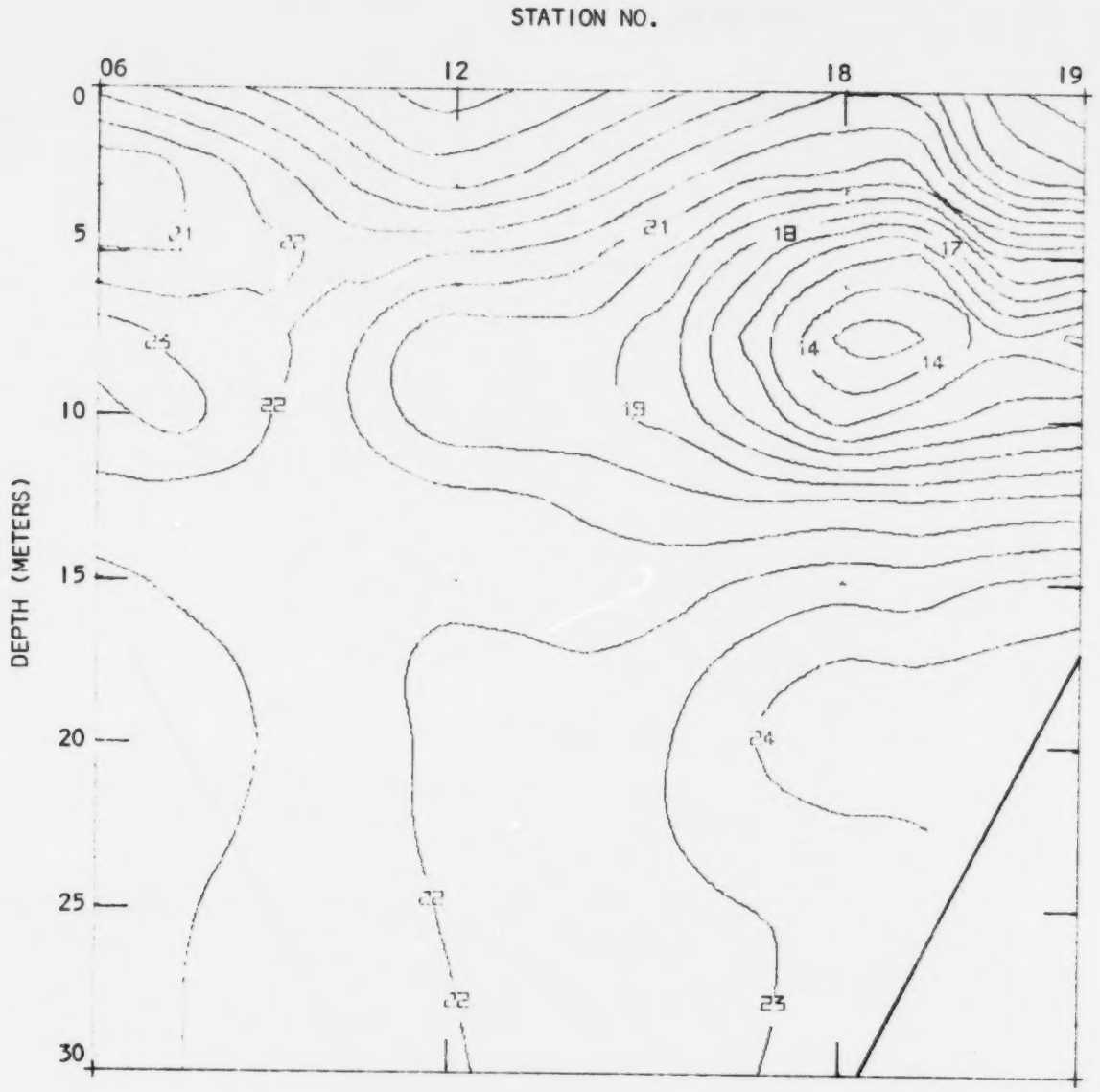
SYDNEY 1 STA06-12-18 19 TRANSECT TEMP PROFILE .01 DEG C



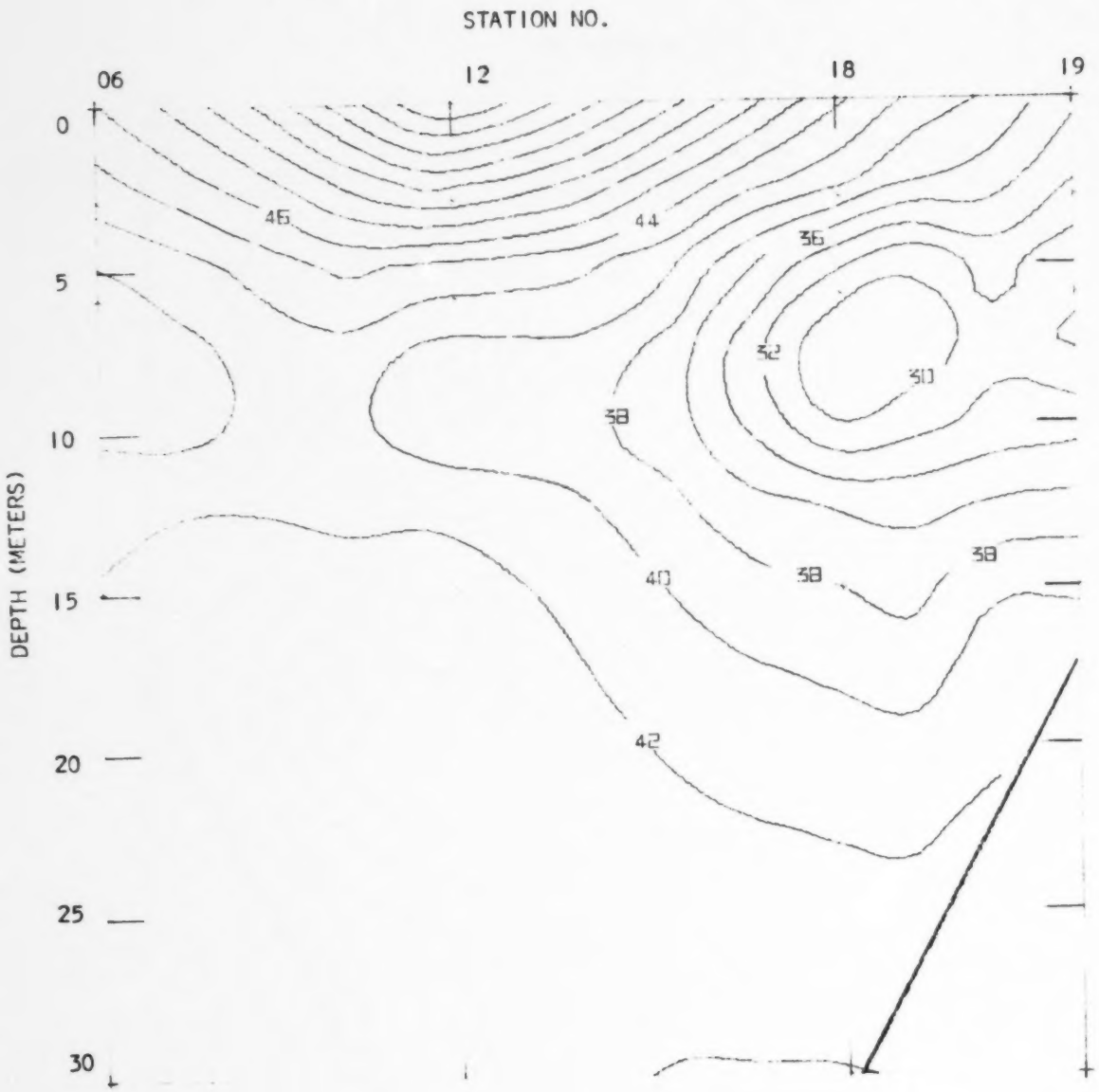
SYOPS 1 STA 06-12-18 19 TRANSECT SALINITY PROFILE PFB



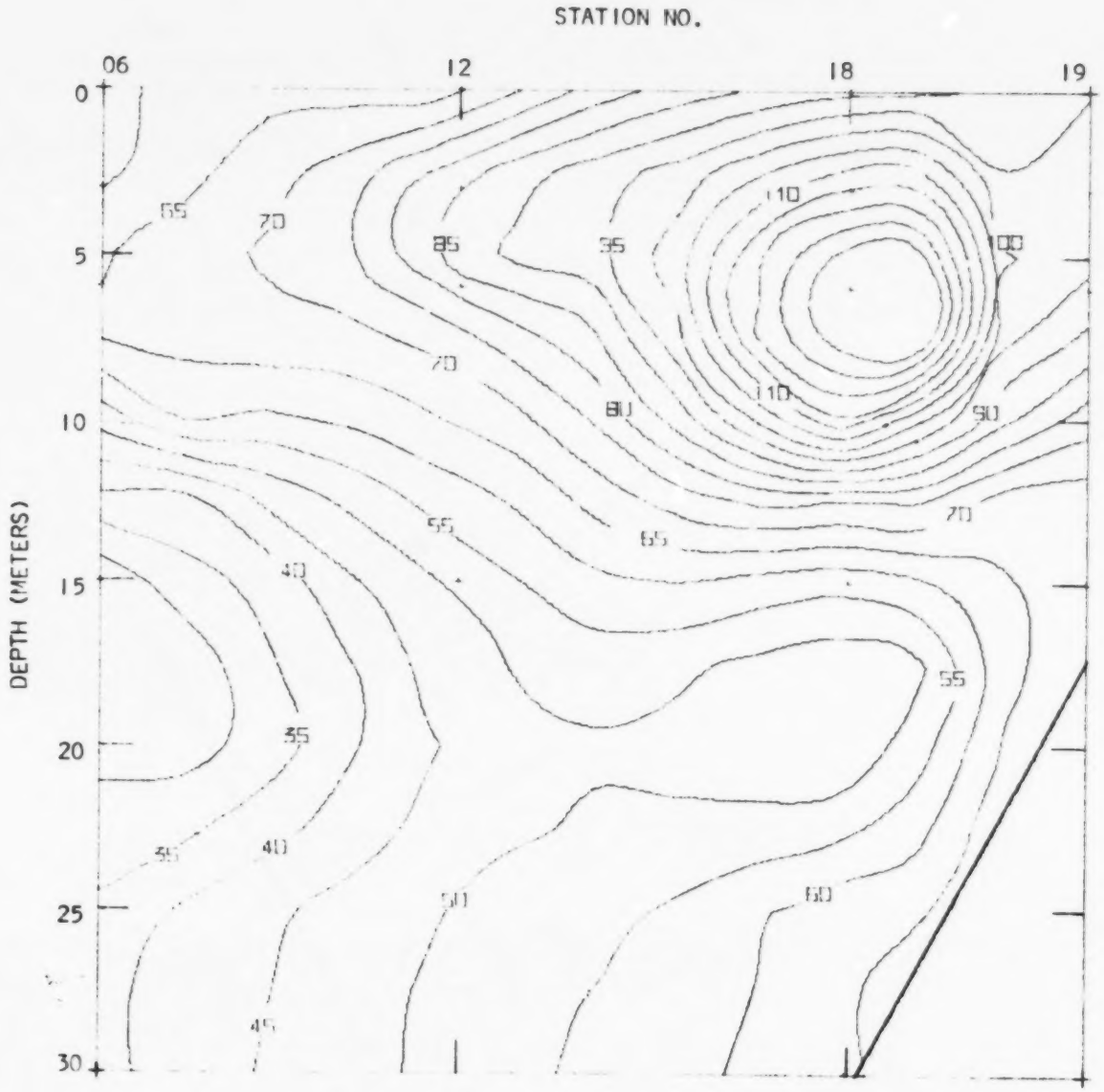
SYOPS 1 STA 06-12-18-19 TRANSECT OXYGEN PROFILE .001 MG-AT/L



SYOPS 1 STA 06-12-18-19 TRANSECT NITRATE PROFILE 1 µG-AT/L



SYSTEM 1 STA 06 12 18 19 TRANSECT SILICATE PROFILE 1 µG-AT/L

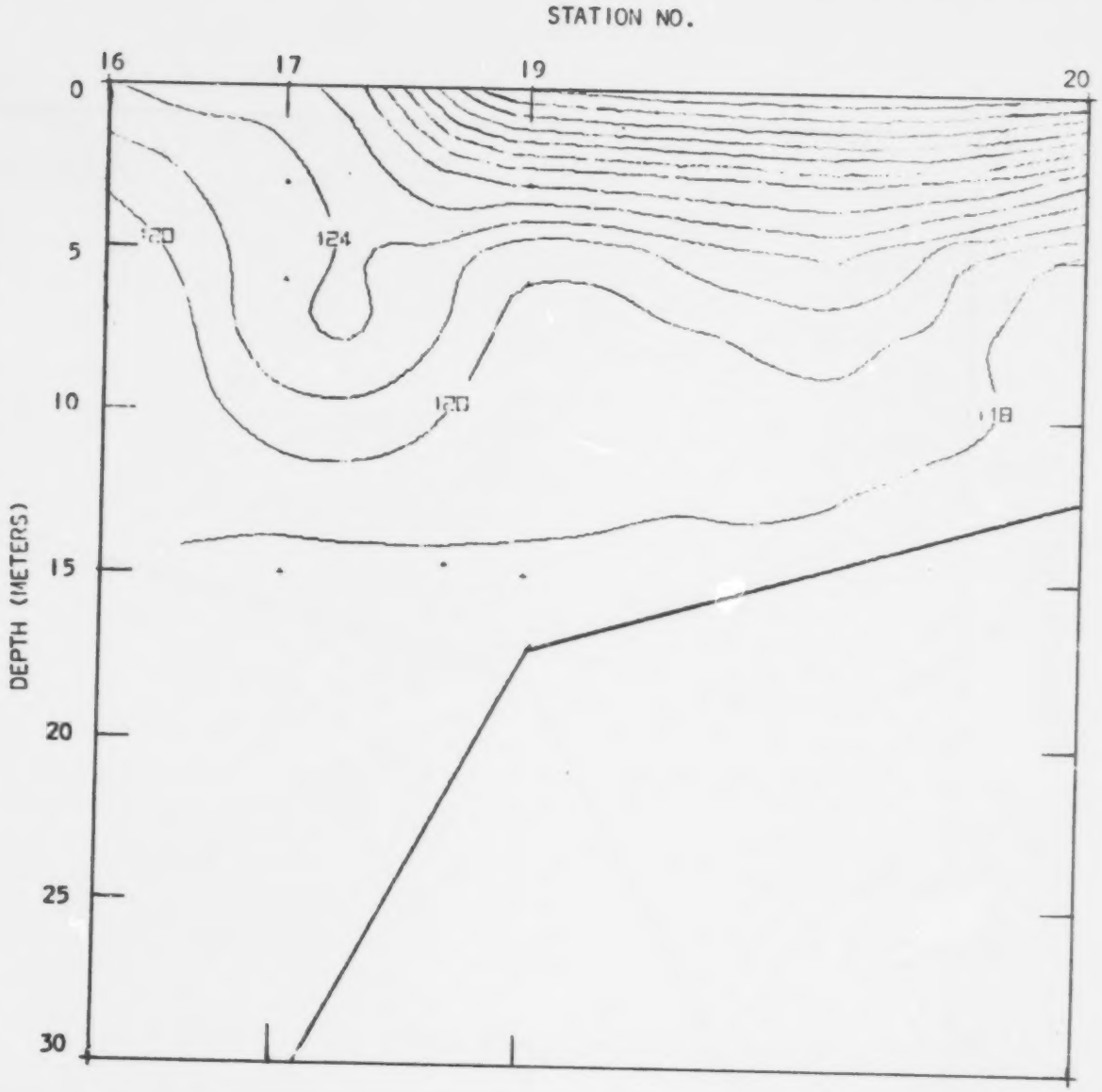


SYCRS 1 STA 06-12-18-19 TRANSECT CHLOROPHYLL A PROFILE .01MG/L

Station 16-17-19-20 transect

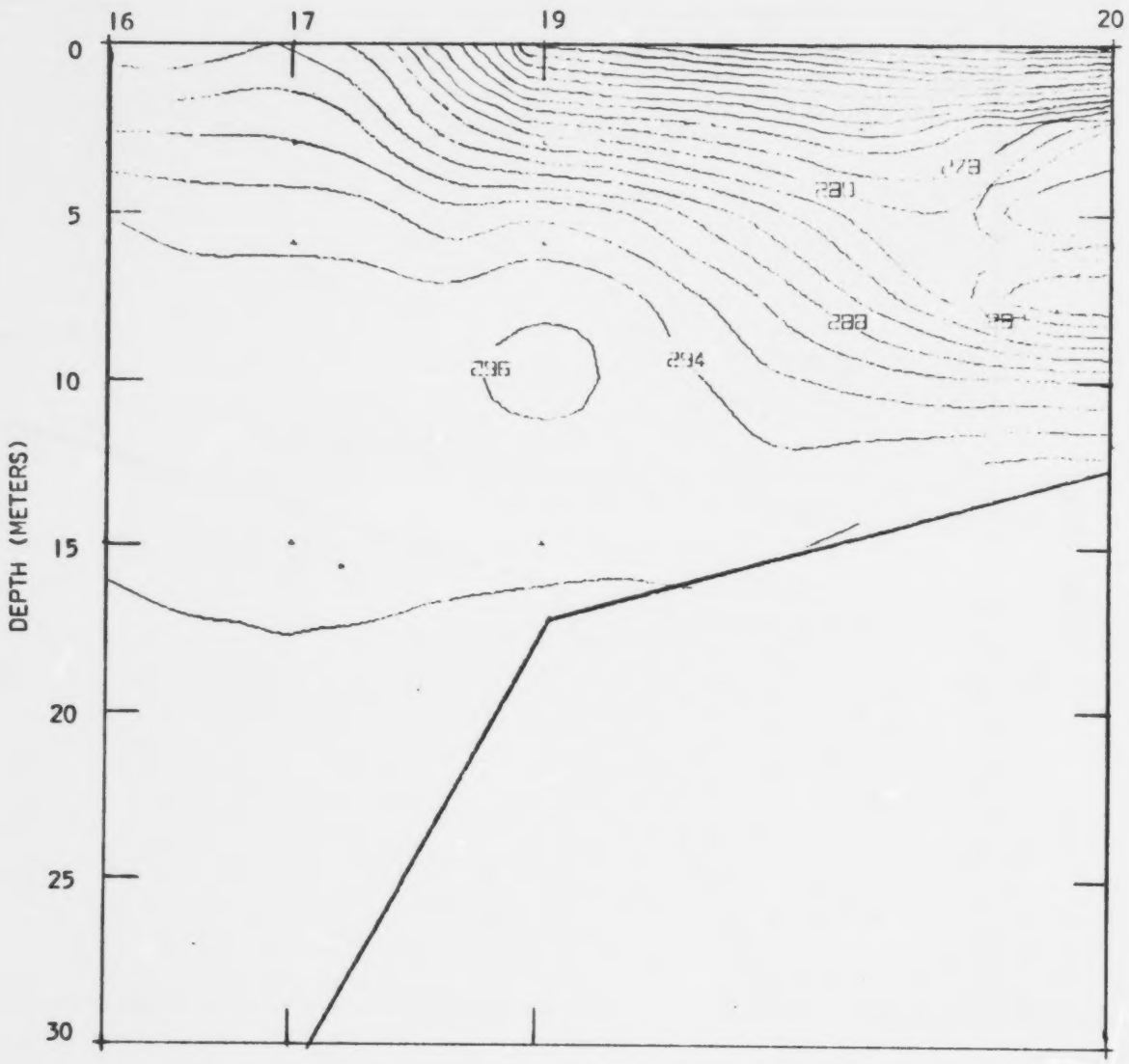
Preceding page blank

121

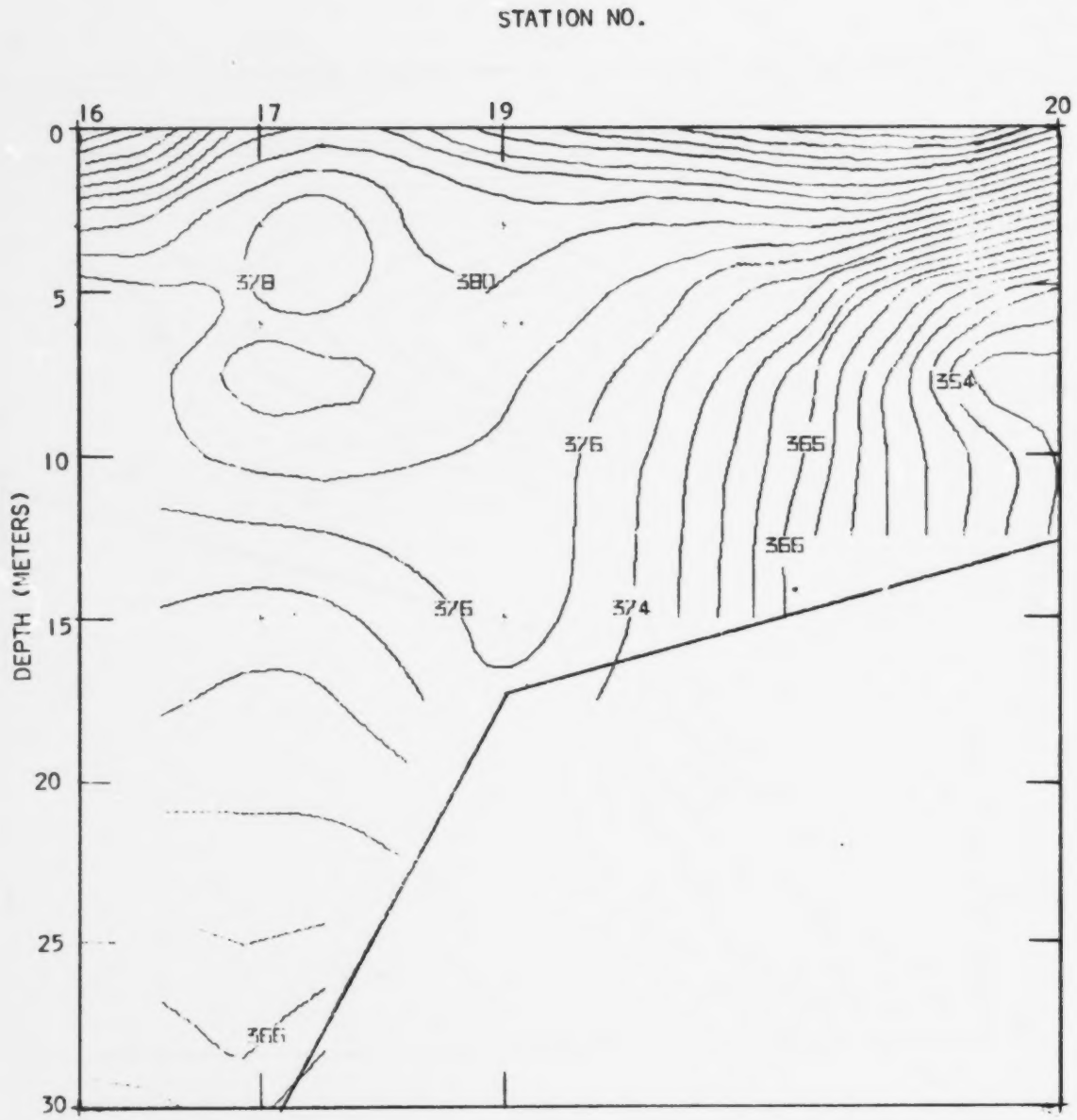


SYOPS 1 SYA 16-17-19-20 TRANSECT TEMP PROFILE .01 DEG C

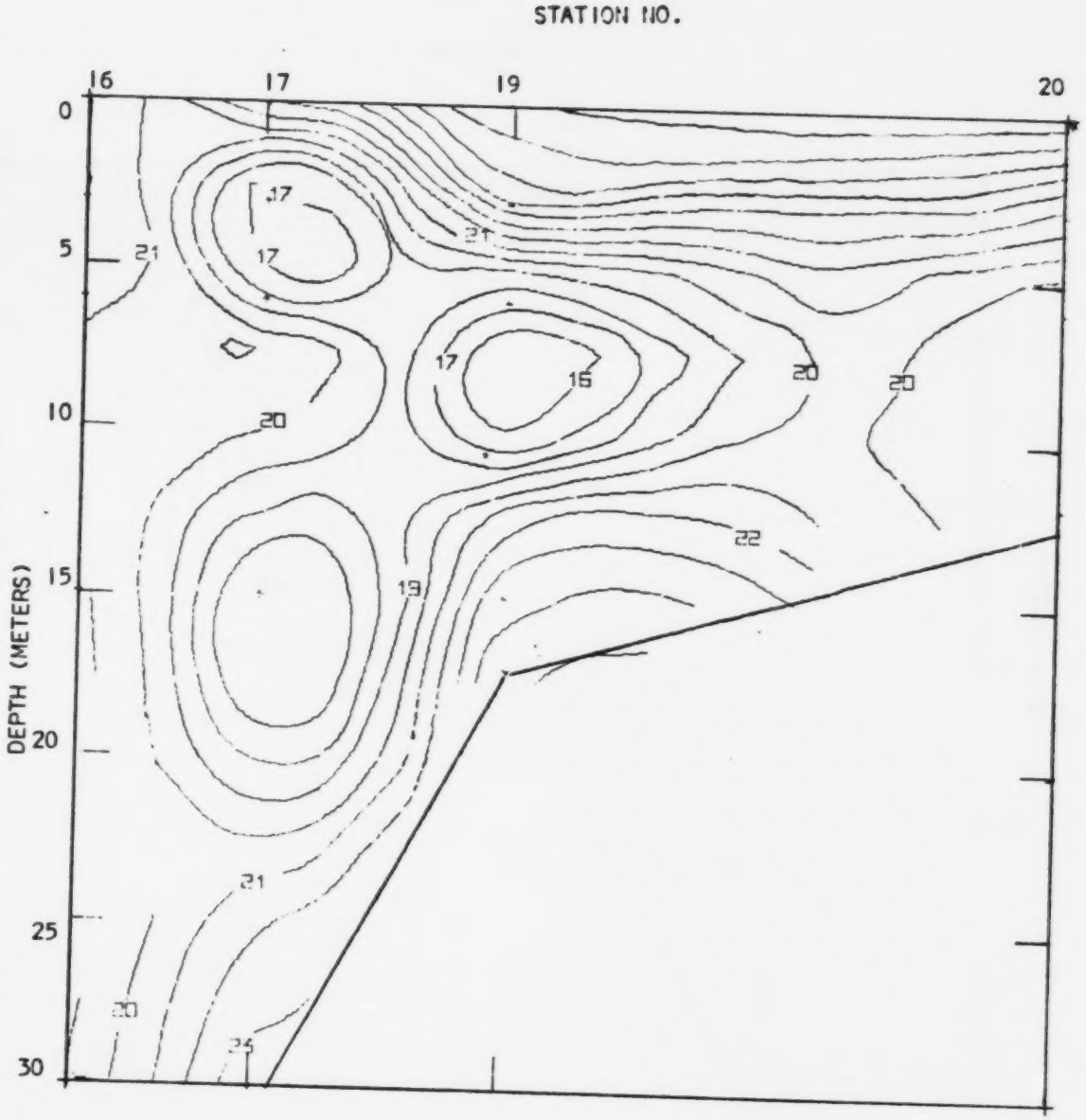
122
STATION NO.



SYOPS 1 STA 16-17-19-20 TRANSECT SALINITY PROFILE PPB

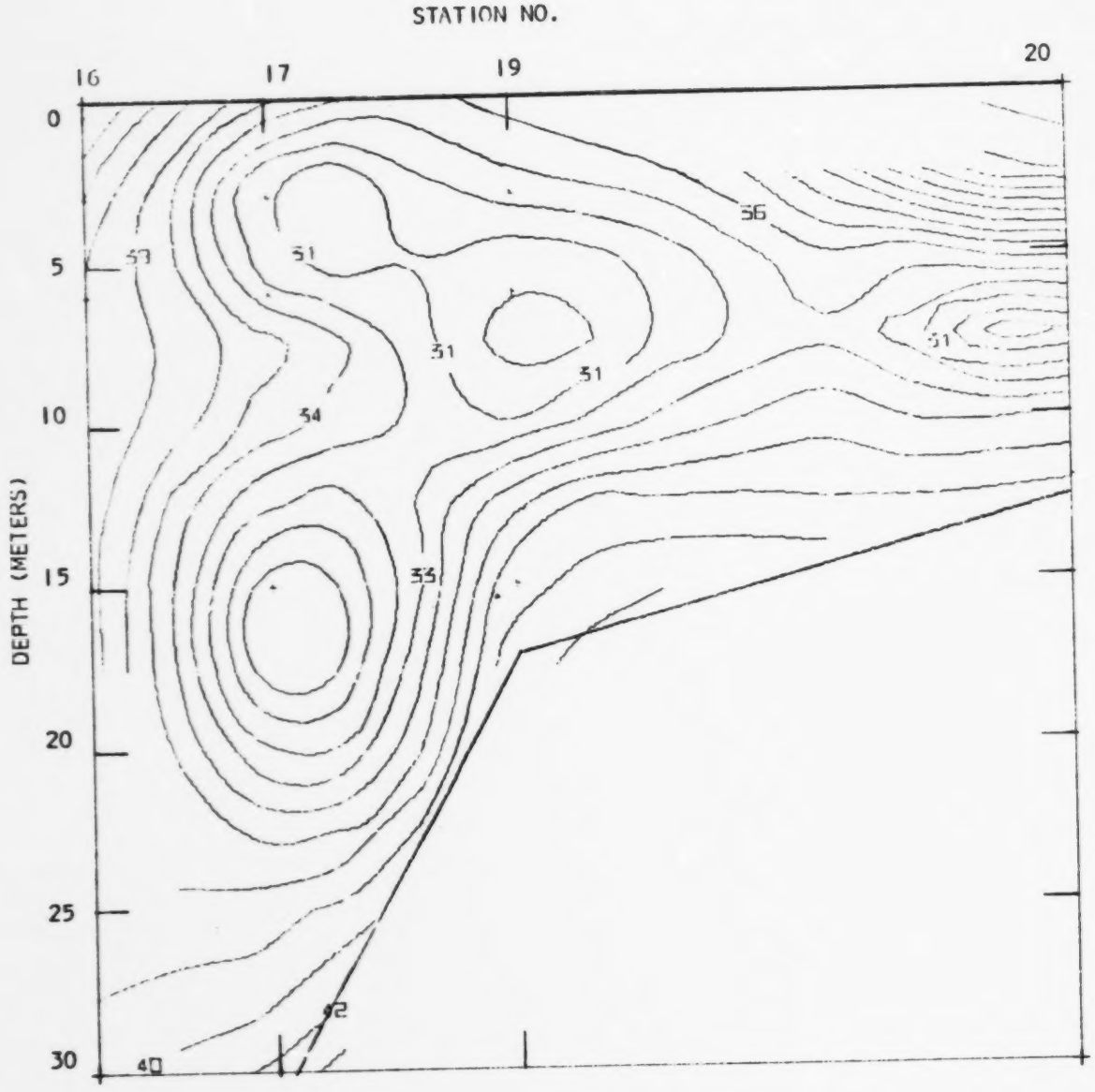


SYSTEM 1 DATA 16-17-19-20 TRANSECT OXYGEN PROFILE (OOJMG-AT L



SYOPS 1 STA 16-17-19-20 TRANSECT NITRATE PROFILE 1 UG-AT/L

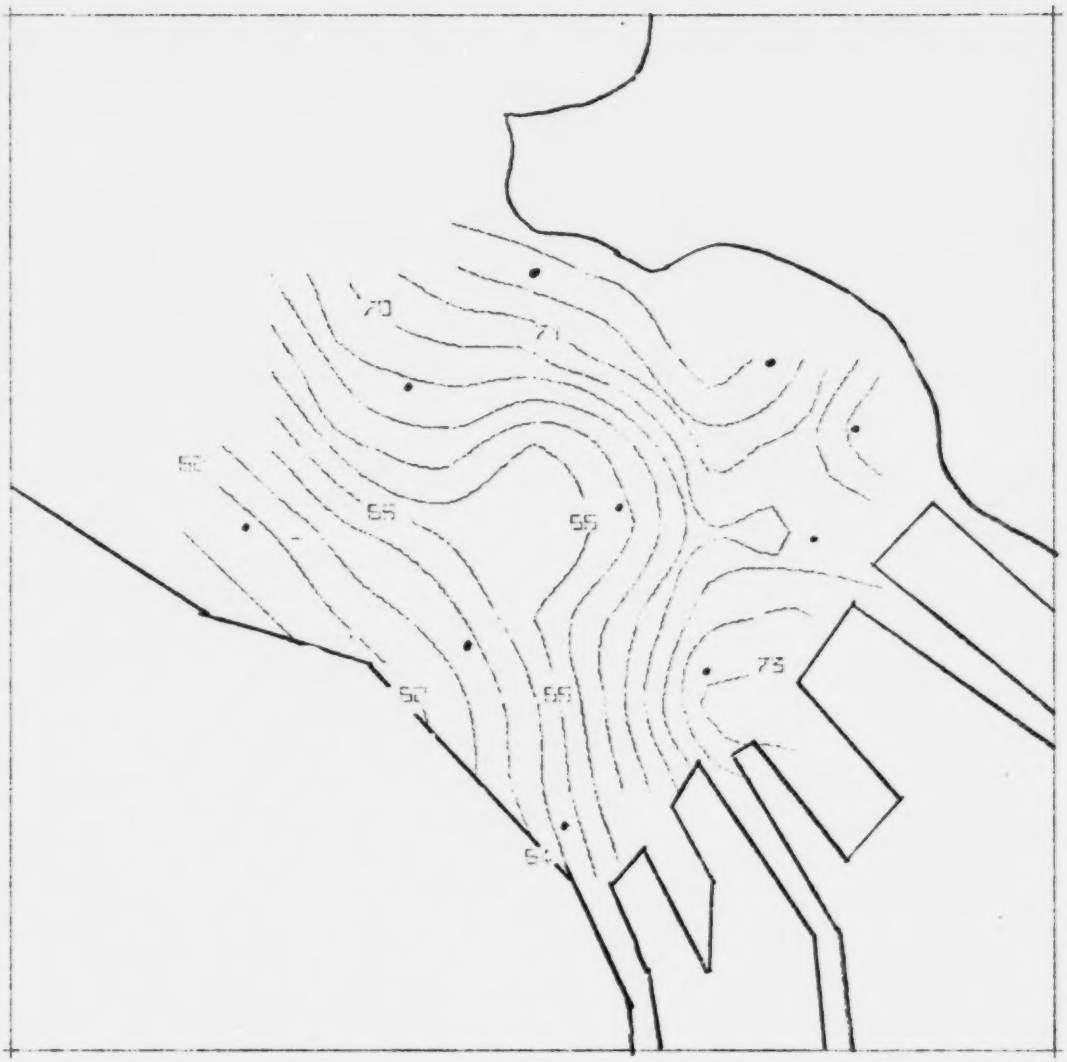
124



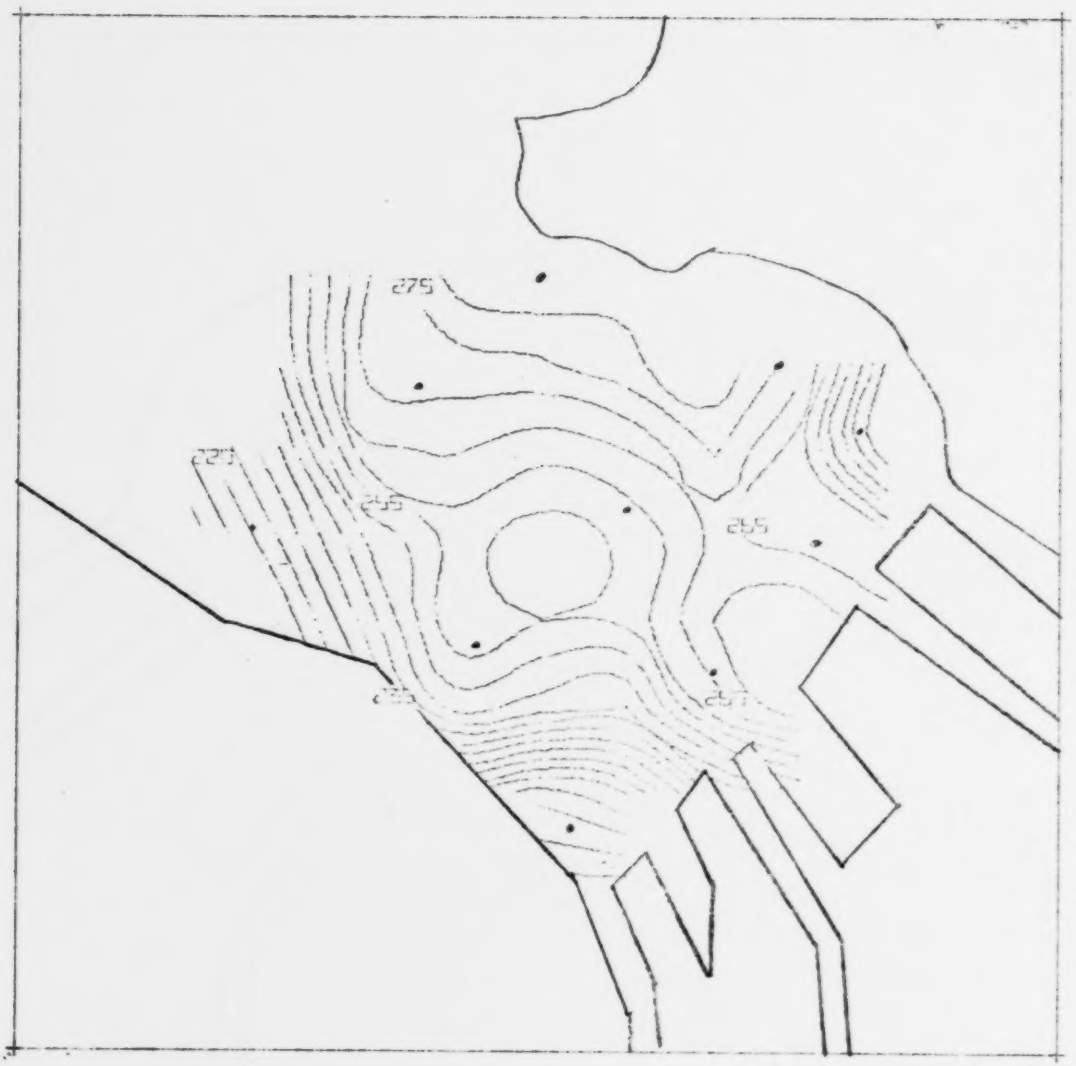
SYOPS 1 STA 16-17-19-20 TRANSECT SILICATE PROFILE 1 UG-AT/L

HORIZONTAL CONTOUR PLOTS (SYOPS-3)

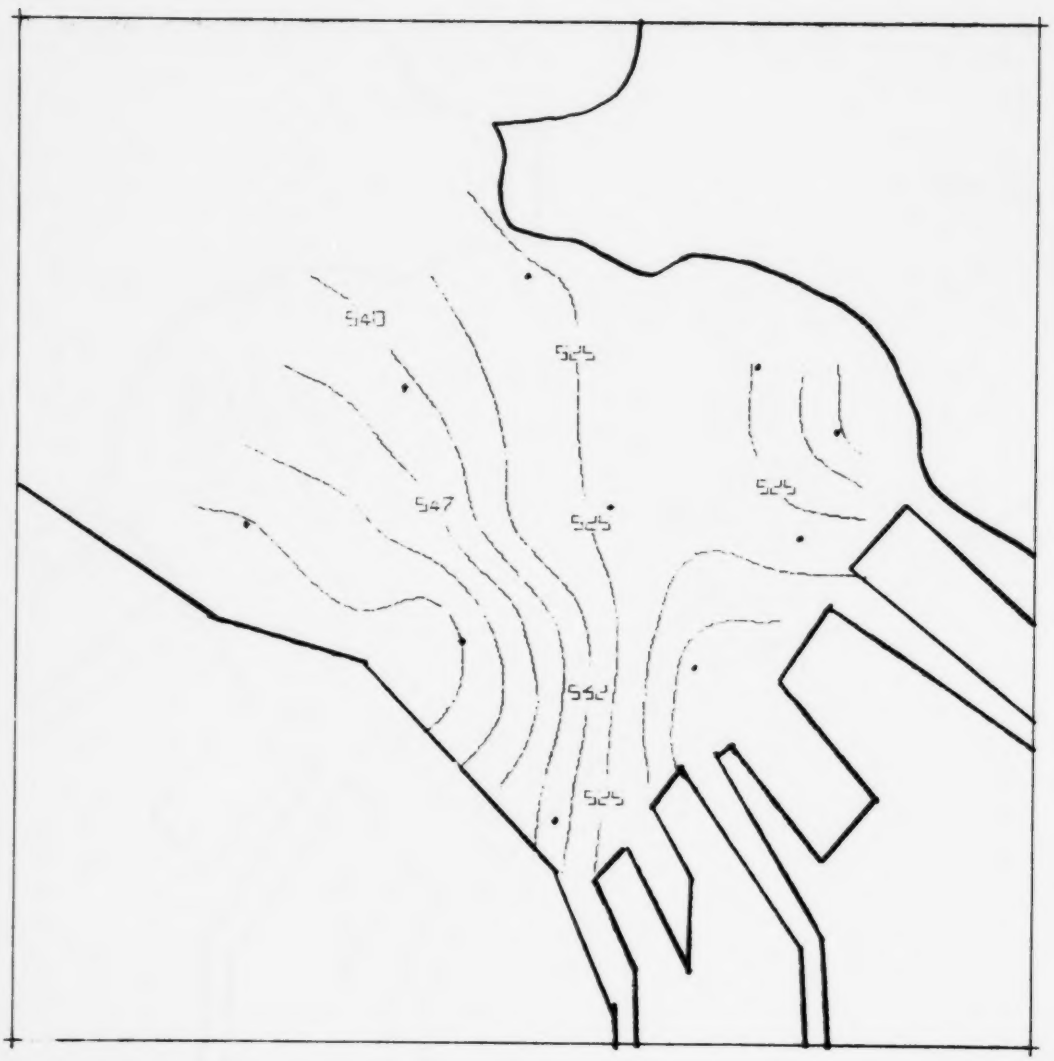
00 Meter Surface



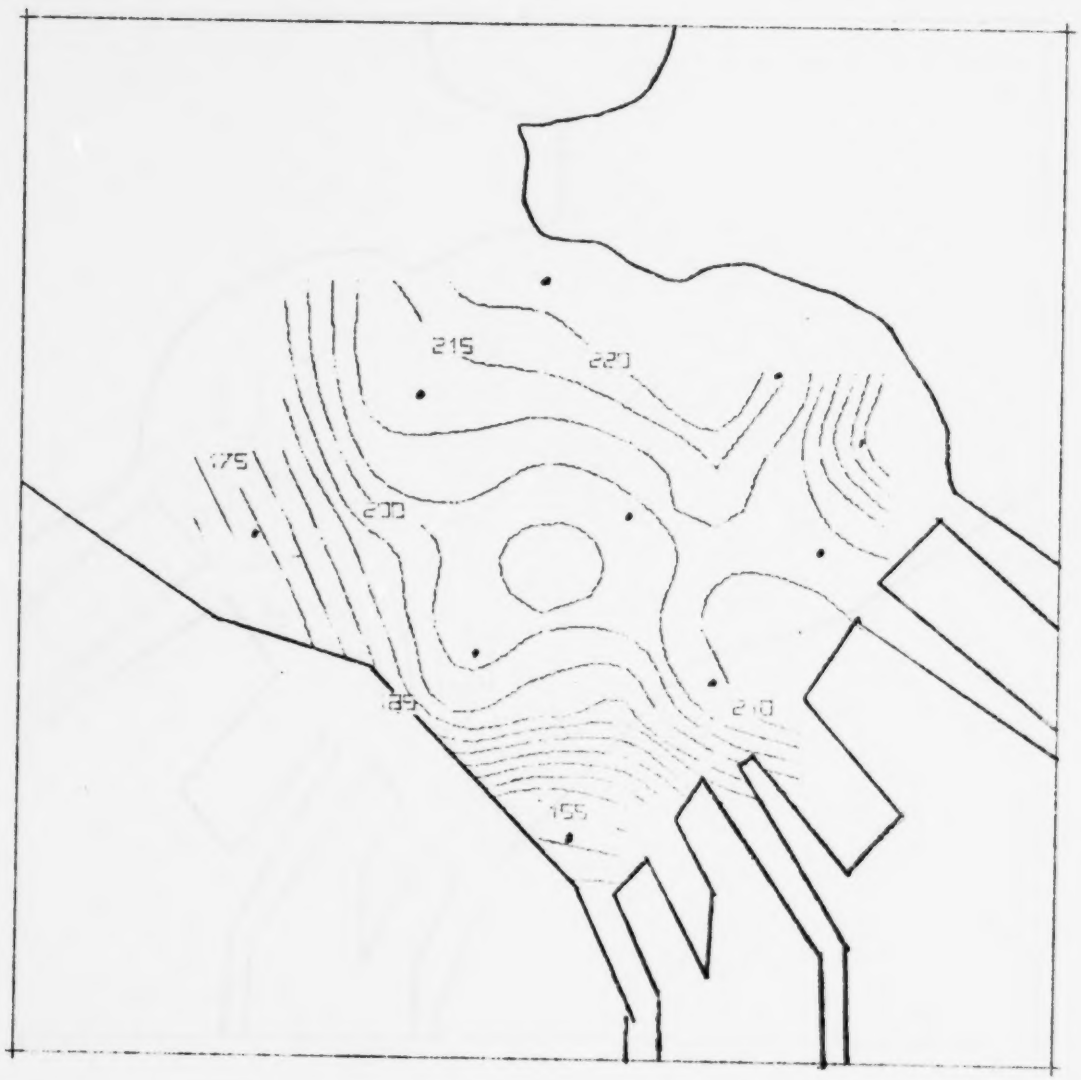
SYOPS, 3 CM TEMPERATURE 0.1 DEG. CENT.



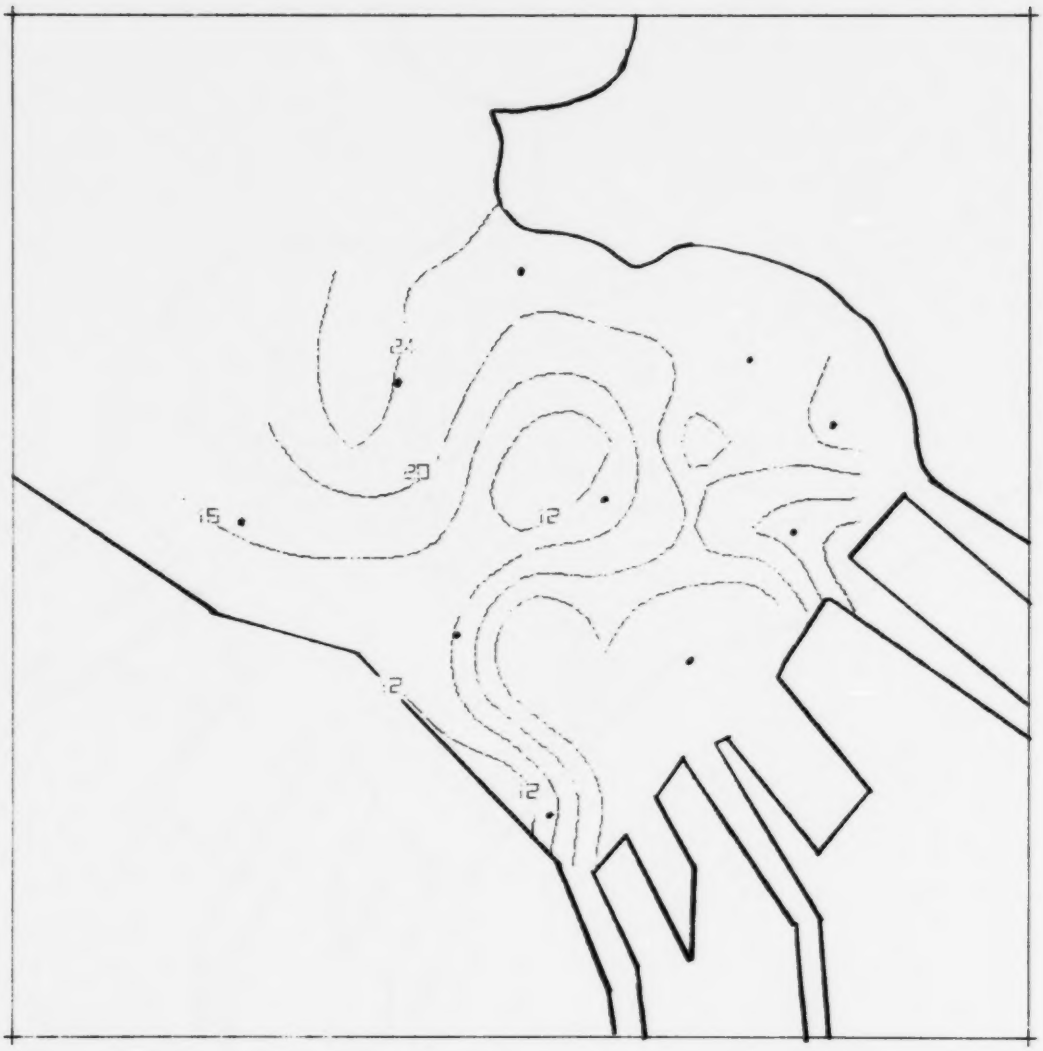
SYSTEM 3 ON SALINITY 100 PPM



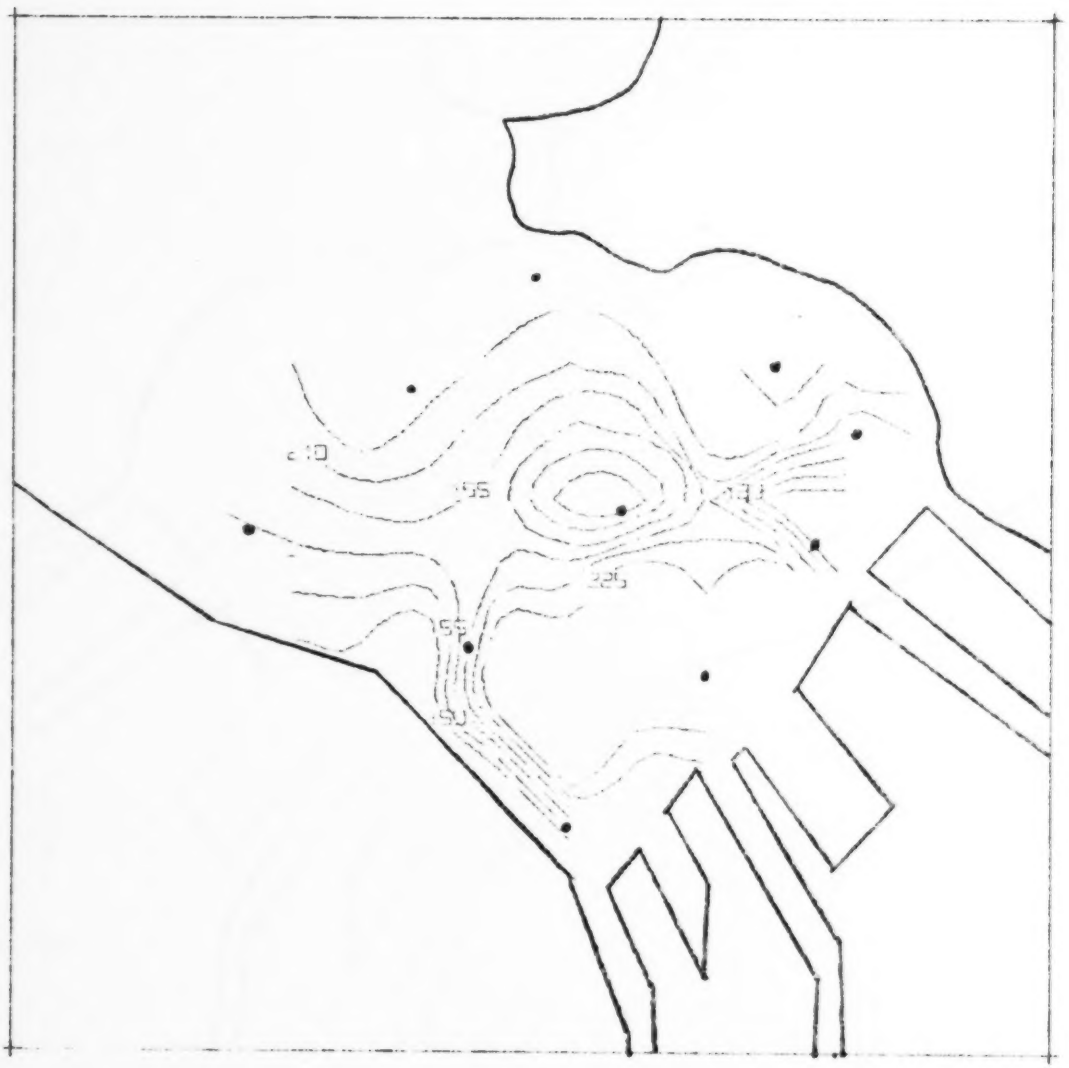
SYOPS 3 OM OXYGEN O·CO1 MG-AT/L

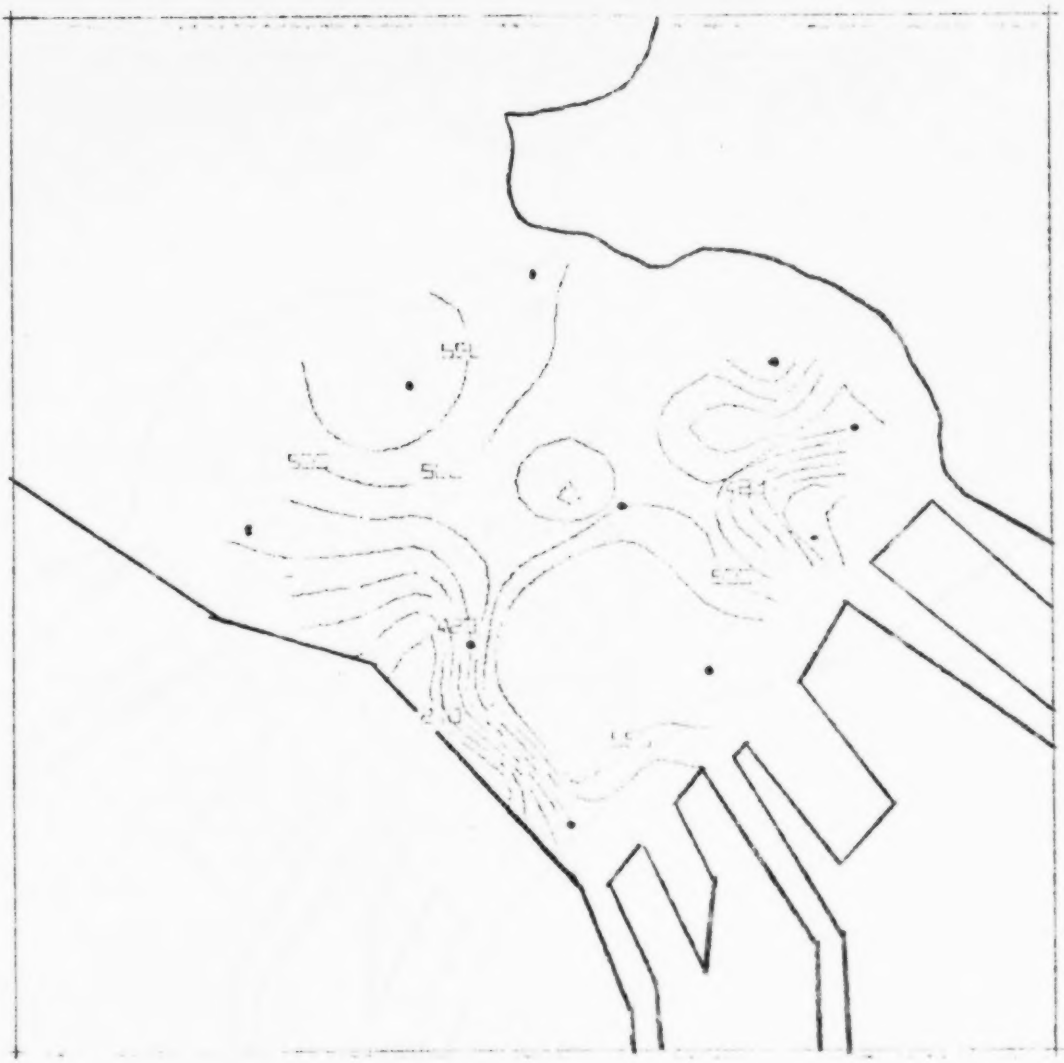


SIGMA-T (AM SIGMA-T O-L SIGMA-T UNIT



SYCOPS 3 OM NITRATE 1 µG-AT/L





SILICATE

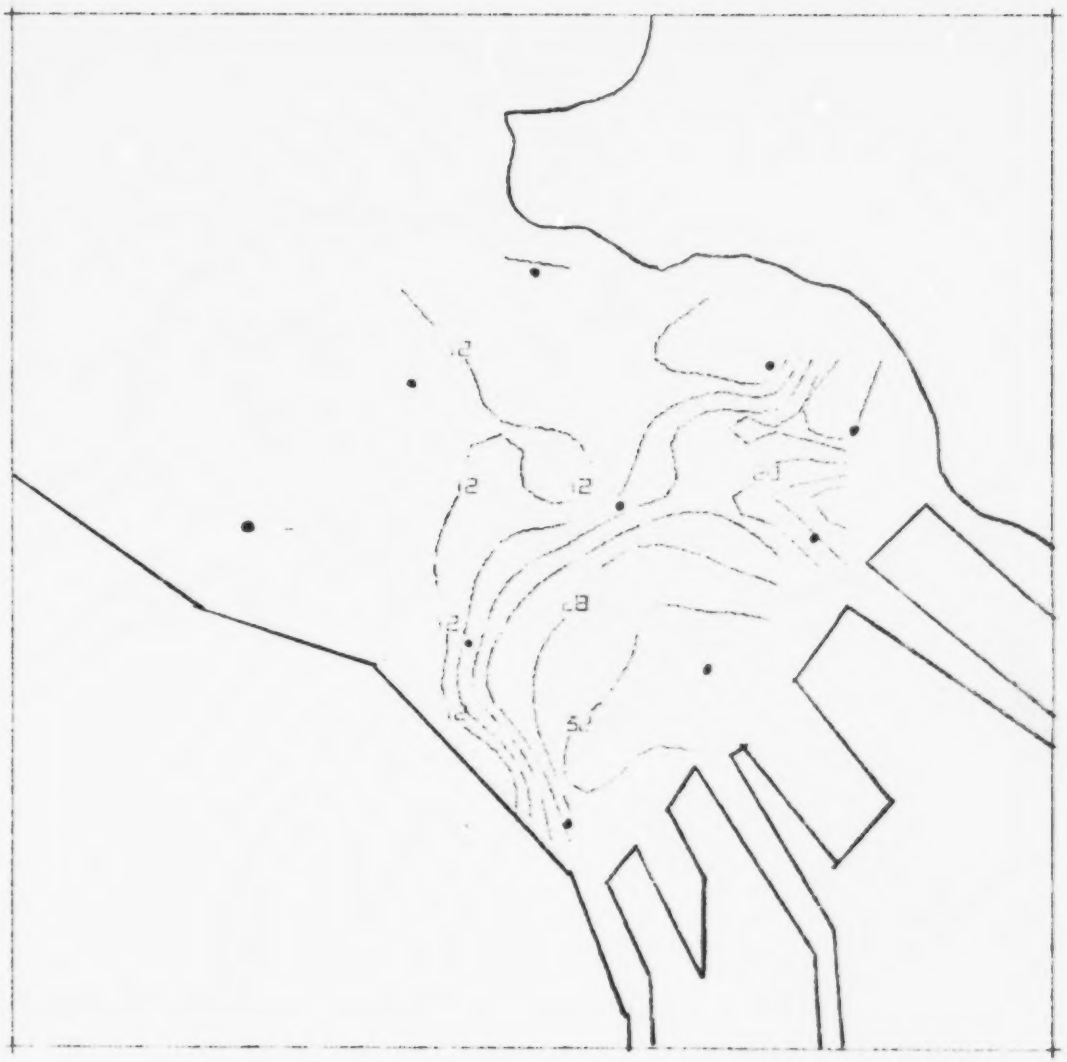


FIGURE 3 ug CHLOROPHYLL A ug/L

CHLORINATED HYDROCARBON DATA[1]

[1]This report is not a complete compilation of chlorinated hydrocarbon data. Virtually all sediment analyses have been completed. Zooplankton values are available only for SYOPS-4. Analyses of the remainder of the zooplankton and the particulates is pending.

Preceding page blank

TABLE I. SYOPS (2, 3, 4) PCB Sediment Data[a]

STATION	PCB	p,p'-DDE	p,p'-DDD	p,p'-DDT[b]	ΣDDT	ΣDDT/PCB
1						
2						
3						
4	190	ND	ND	ND		
5	224	ND	ND	3	3.0	0.013
6	220	3	0.5	ND	3.5	0.16
7						
8						
9						
10	34	1.17	0.55	1.06	3.38	0.10
11	170	ND	Tr	ND		
12	2280	ND	Tr	ND		
13	2500	ND	TR	ND		
14						
15						
16	395	7.0	ND	6.0	13.0	0.03
17	180	ND	ND	ND		
18	500					
19	330					
20	2440	20.4	ND	ND	20.4	0.008
21	31.2	0.13	0.095	0.048	0.27	0.09
22						
23	64.7	2.54	1.82	3.3	4.69	0.07
24	18.4	0.93	ND	Tr	0.93	0.05
25	13.5	0.98	0.43	0.43	1.84	0.14
26	43.0	ND	ND	ND		
27	12.6	0.8	Tr	ND	0.8	0.06
28						
29	27.7	1.66	1.33	0.67	3.66	0.13
30	13.0	0.92	Tr	ND	0.92	0.07

TABLE I. (continued)

STATION	PCB	p,p'-DDE	p,p'-DDD	p,p'-DDT	ΣDDT	ΣDDT/PCB
31						
32						
33						
34	0.19	0.18	ND	ND	0.18	0.95
35	2.5	0.45	0.09	ND	0.54	0.22
36						
37	11.7	1.0	ND	Tr	1.0	0.09
38						
39	24.4	1.68	1.26	0.5	3.44	0.14
40	2.0	0.23	0.11	0.11	0.45	0.23
41	7.1	0.77	0.95	0.30	2.02	0.28
DR 2[c]	77	ND	ND	2.4	2.4	0.03
DR 8	1297	ND	26.0	50.0	76.0	0.06
DR 9	610	ND	ND	10.0	10.0	0.02
DR 10	333	ND	ND	8.1	8.1	0.02

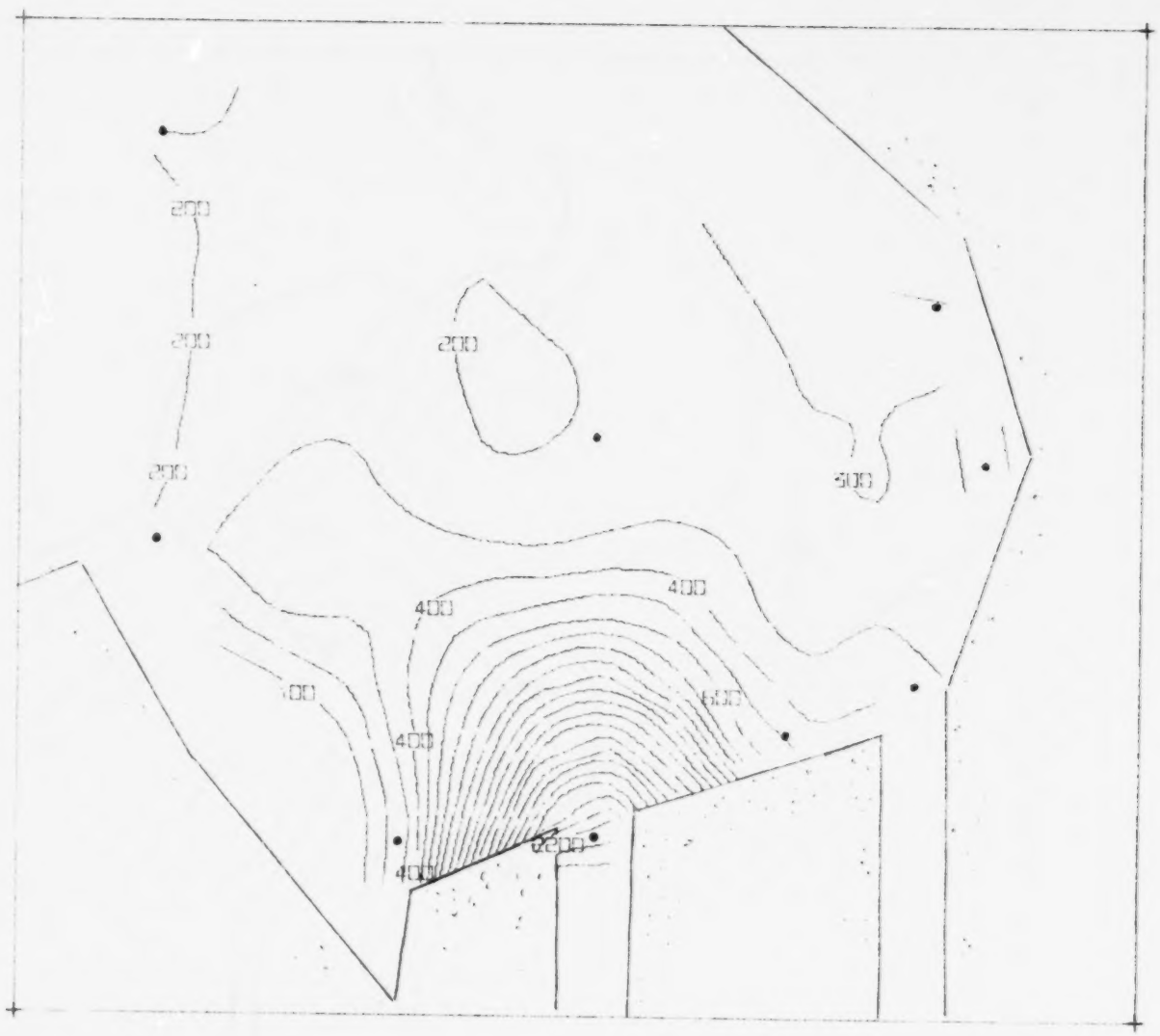
[a] In micrograms per gram of dry weight sediment (ppb).

[b] For Stations 1-20 the DDT homolog values are estimated.

[c] Duwamish River stations.

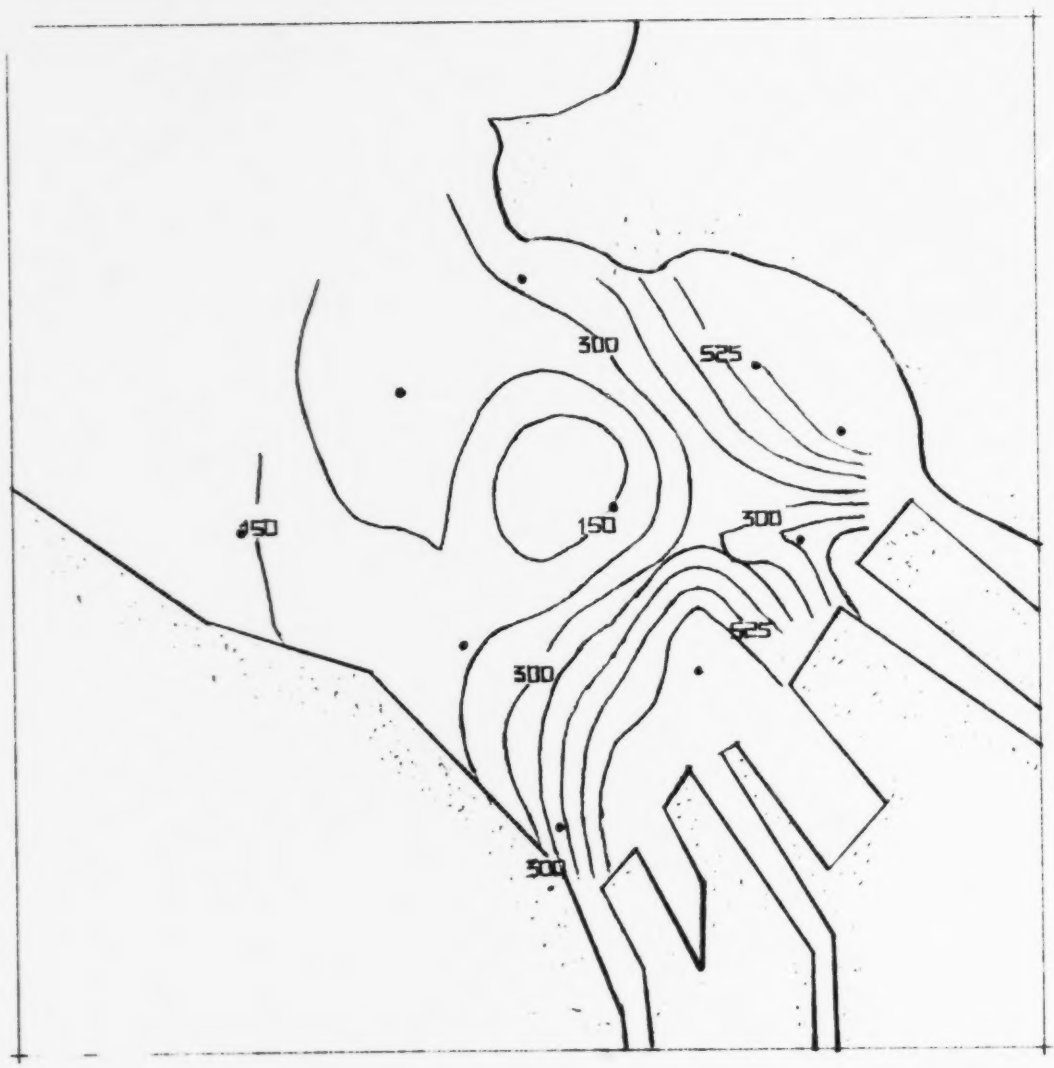
ND not detected

Tr trace present



SYOPS I PCB PPB

SURFACE SEDIMENTS



[illegible] TOTAL PCB IN SEDIMENTS 0.1 PPB

[illegible] TOTAL DDT IN SEDIMENTS 0.01 PPB

SYOPS 4 CHLORINATED HYDROCARBON CONCENTRATIONS IN ZOOPLANKTON[a]

Station Number	Water Depth (m)		Volume Seawater Filtered (m^3)	Total Biomass (wet weight)		% Lipid[e] g/g	CH Concentrations[c] ng/g (µg/g)				
	Actual, (MLLW)[b]	Sampled		g/tow	g/m^3		PCB[d]	DDT Analogs			
								pp'DDE	pp'DDD	pp'DDT	ΣDDT
3	100	57	251.3	169.6	0.67	0.40	11.5	0.3	0.5	0.2	1.0
							(2.88)	(0.08)	(0.12)	(0.05)	(0.25)
10	75	33	122.9	128.2	1.04	0.17	20.3	0.3	0.7	0.4	1.4
							(11.94)	(0.18)	(0.41)	(0.24)	(0.82)
5	75	57	127.4	58.9	0.46	0.67	22.6	0.9	1.1	0.5	2.5
							(3.37)	(0.13)	(0.16)	(0.07)	(0.37)
11	75	70	93.2	74.0	0.79	0.43	19.5	0.5	0.5	0.5	1.5
							(4.53)	(0.12)	(0.12)	(0.12)	(0.35)

[a]Ctenophores and hydromedusae were the predominant zooplankton forms at all stations, with 5 and 11 showing abundant juvenile euphausiids relative to the northern stations. A small number of copepods, crab zoea larvae, chaetognaths, and amphipods were noted at all stations.

[b]Mean lower low water

[c]Concentrations without parentheses are on a ppb wet weight basis and those in paretheses are on a ppm lipid weight basis.

[d]PCB quantitated as Aroclor 1254

[e]Lipid being defined as solvent extractable material with a 2:1 (v/v) hexane-acetone mixture.

Preceding page blank

Preceding page blank

TRACE METALS (DISSOLVED)

SYOPS-I

Station No.	Depth (M)	Concentration (µg/l)	
		Cu	*Zn*
1	00	0.15	0.16
	15	0.15	0.40
11	00	0.40	0.37
	15	0.12	0.15
12	00	0.40	0.44
	15	0.07	0.13
13	00	0.15	0.16
	15	0.15	0.40
14	00	0.45	0.17
	15	0.47	0.27
15	00	0.07	0.44
	15	0.11	0.16

Preceding page blank

APPENDIX I

SAMPLING METHODOLOGY FOR CHLORINATED HYDROCARBONS

Preceding page blank

A DESCRIPTION OF THE LARGE VOLUME FILTER

A schematic diagram of the large volume filter system (LVF) is given in Figure 1. The LVF is designed to collect large quantities of suspended particulate matter with minimum contamination from the system that would interfere with trace organic analysis.

The intake line and filtering chamber are constructed of stainless steel while the remainder of the flow lines are standard galvanized iron pipe. Seawater, drawn into the system by vacuum, passes initially through a precombusted 8" x 10" glass fiber filter (Reeve Angel 934AH, Whatman GF-C, or similar), suspended on a stainless steel screen in the filtering chamber, then through a totalizing water meter (Hersey Water Meter MHF), and finally discharges into an evacuated ballast (50ℓ glass jug). Vacuum in the ballast is maintained by a rotary vane vacuum pump (Millipore XX60 000 000). The vacuum is set to compensate for lifting the seawater to the filter head and produce less than 1/2 atmosphere pressure drop across the filter, minimizing cell disruption. The water collected in the ballast is continuously discharged via a positive displacement water pump (Teel rotary screw pump model 1P610, 280 gpm capacity) to maintain a proper level.

The pumping characteristics of the LVF system are variable, depending mainly on the suspended particulate load. However, in most areas sampled, filtering rates in excess of 300 liters per hour were attained.

A ZOOPLANKTON NET FOR EXCLUDING SURFACE FILM COMPONENTS

Net Construction. The net, as shown in Figures 2 and 3, is a modified version of a Juday net (Juday, 1916). The filtering material consists of a Nitex® nylon monofilament screen cloth (333μ mesh size)[1]. A six-ounce nylon utility cloth

---

[1]A hexane extract of the preused Nitex® screen cloth analyzed by gas chromatography showed no impurities which might interfere with the CH quantitated in the zooplankton samples.

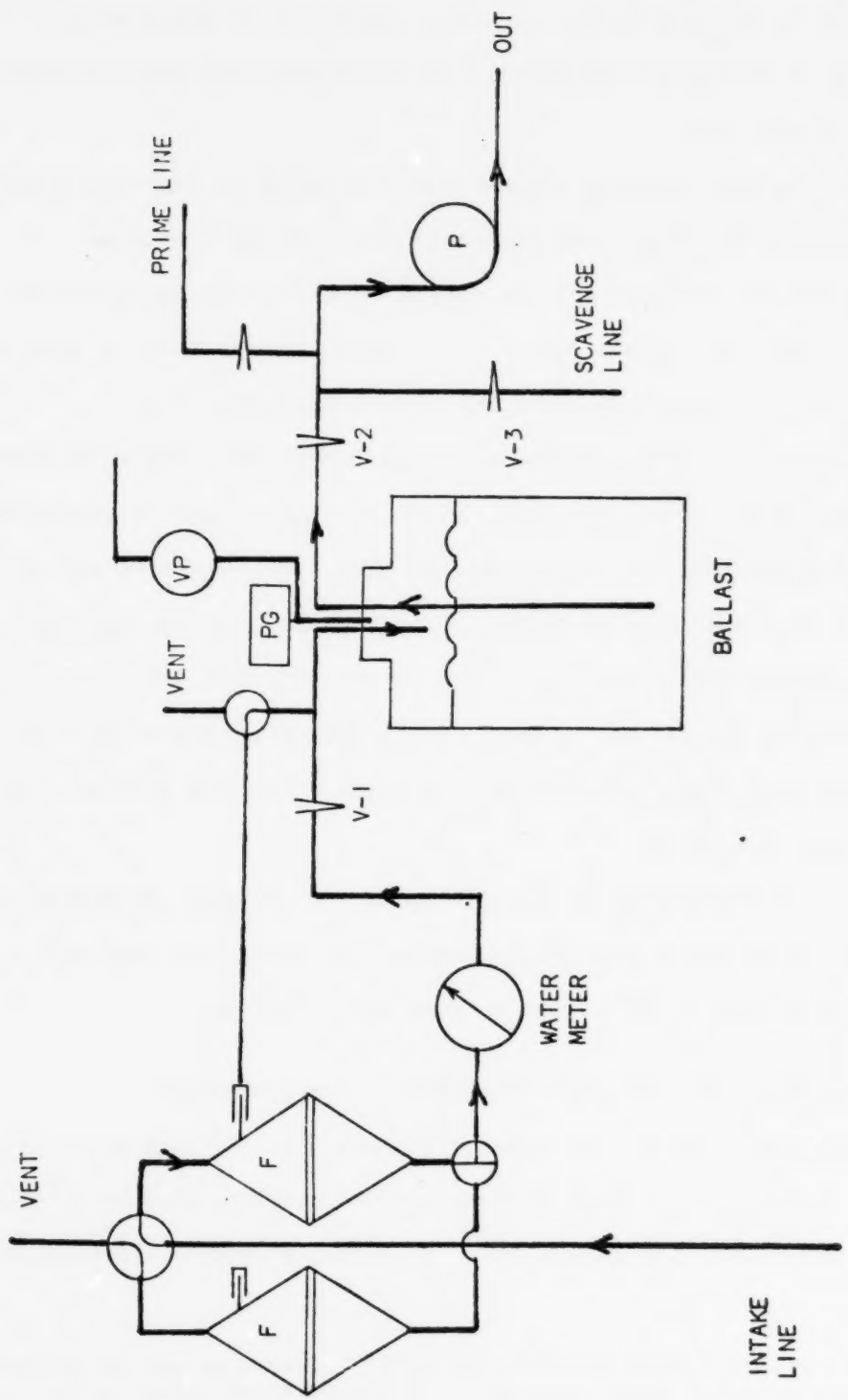


FIGURE 1. SCHEMATIC DIAGRAM OF THE LV FILTER

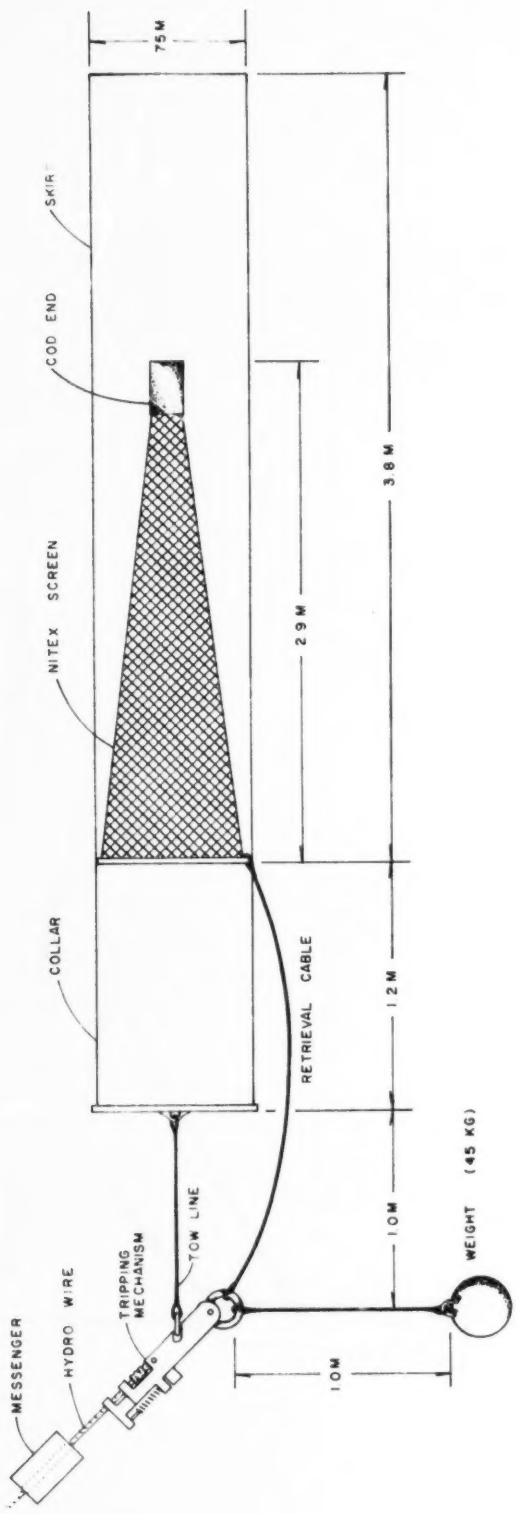
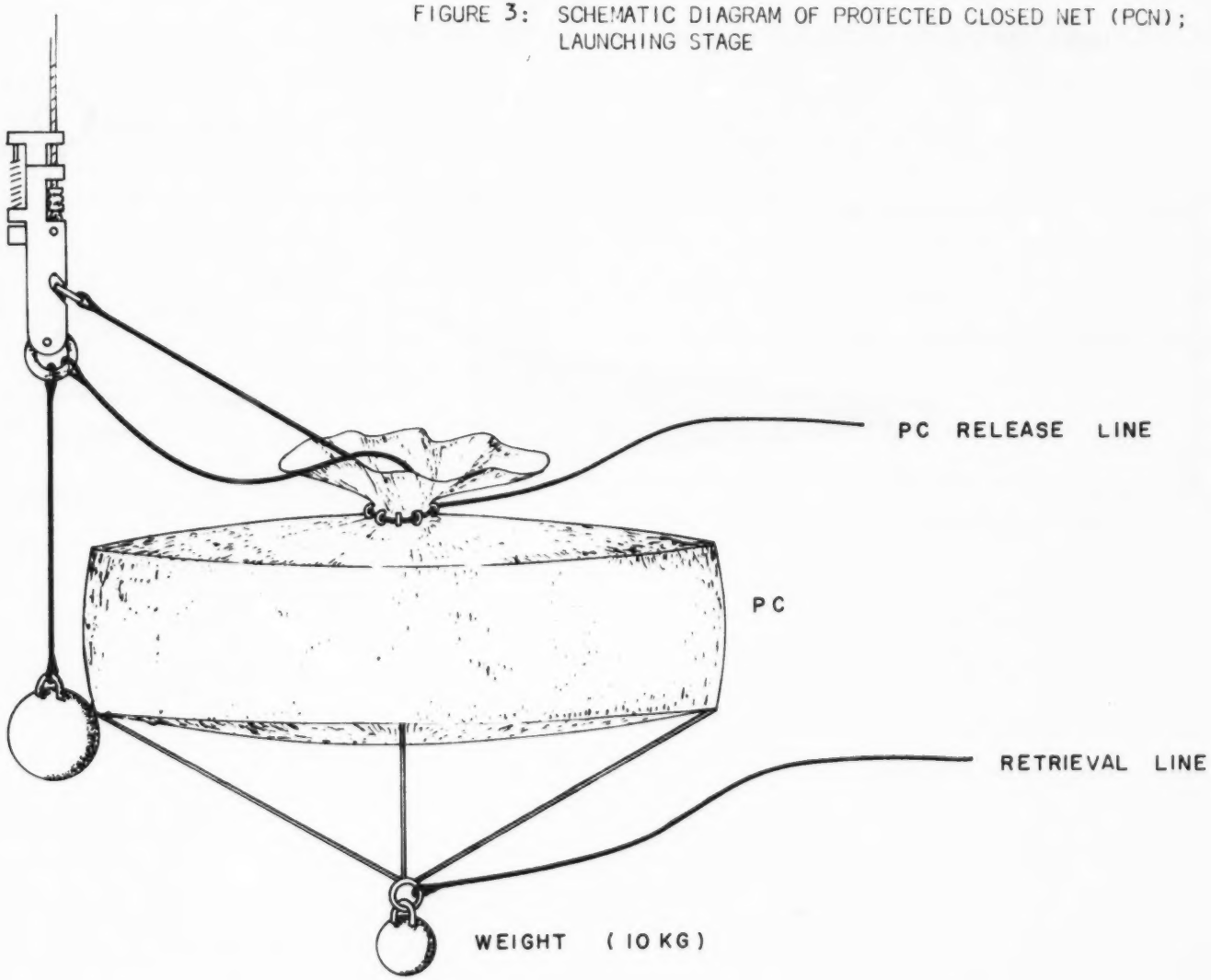


FIGURE 2: SCHEMATIC DIAGRAM OF PROTECTED CLOSED NET (PCN); DEPLOYED STAGE

FIGURE 3: SCHEMATIC DIAGRAM OF PROTECTED CLOSED NET (PCN); LAUNCHING STAGE



was used for the collar, skirt and the protective cover, as shown in Figures 2 and 3. The skirt covers the net completely upon retrieval through the water surface. A brass cod end with a Nitex® screen cloth window (216μ mesh size) was used to collect the plankton.

Towing Procedure. Due to the low porosity of the protective cover a 45 kg weight is used to pull the enclosed net below the water surface as shown in Figure 3. After immersion the release line is retrieved from the protective cover, allowing the latter to fall away from the net; towing is then initiated. Before retrieval of the net through the water surface, the tripping mechanism is activated and the mouth of the net is closed. For vertical tows the 45-kg weight is attached to the second support ring.

Net Efficiency. The filtration efficiency of the net is defined as

$$F = \frac{V_n}{V_m}$$

where V_n is the volume of water filtered by the net and V_m is the volume swept by a bare ring. Both volumes have been calibrated by flow measurements using a TSK flowmeter (Nakai, 1954) positioned midway between the rim and the center of the forward ring. A 100% efficiency for the bare ring was assumed. From replicate measurements, a filtration efficiency of 0.77 was calculated.

Surface Film Exclusion Studies. Identical tows with the protected closed net and an open net of the same mesh size and mouth diameter, were made in Elliott Bay (0.7 nautical miles north of the mouth of the west waterway of the Duwamish River) and Lake Washington on July 10, 1973. The results of the chlorinated hydrocarbon analyses are shown in Table I. Although the average PCB concentration from the replicate tow samples in Elliott Bay was higher in the open than in the protected closed net, this difference was not statistically significant (Student "t" test, $\alpha = 0.10$).

TABLE 1. CHLORINATED HYDROCARBON CONCENTRATIONS[a] IN ZOOPLANKTON SAMPLES[b] FROM NET CALIBRATIONS IN ELLIOTT BAY

Sampling Site	*Closed Net*			*Open Net*		
	Sample No.	PCB[c]	ΣDDT	Sample No.	PCB[c]	ΣDDT
		ppb			*ppb*	
Elliott Bay	T-1	14.7	0.6	T-4	15.2	0.6
	T-2	9.6	0.5	T-5	12.1	0.5
	T-3	7.8	0.4	T-6	14.0	0.6
	Average	*<10.7 ± 3.6>*		*Average*	*<13.8 ± 1.6>*	
Lake Washington	T-7	10.3	8.5	T-8	13.2	11.9

[a] Concentrations are expressed in 10^{-9} g/g wet weight.

[b] In all of the Elliott Bay samples hydromedusae and copepods were the predominant zooplankton forms with small numbers of amphipods, crab zoea larvae, chaetognaths, and juvenile euphausiids. Wood chips and pieces of benthic algae had to be removed from all open net tow samples in Elliott Bay.

[c] PCB concentrations quantitated as Arocior 1254.

However, material known to be concentrated in the surface layers, such as wood chips and pieces of benthic algae, were found in all of the open net and none of the protected closed net samples (the larger debris were removed from the open net samples prior to storage). Such debris presumably entered the open net when it was passing through the water surface, even though care was taken to avoid such an occurrence.

REFERENCES

Juday, C. (1916). Limnological apparatus. *Trans. Wis. Acad. Sci. Arts Lett.*, 18(2): 566-592.

Nakai, Z. (1954). *Manual of the flow meter for a plankton net.* Yokahama, Tsurumi Seiki Kosakusho Co.

Preceding page blank

APPENDIX II

ANALYTICAL METHODOLOGY

FOR CHLORINATED HYDROCARBONS

The techniques used for the analysis of the various samples were, in general, the standard methods presented in the EPA manual (Thompson, 1972). The procedures described below involve modifications to these methods to fit the particular needs of our laboratories.

All solvents used in the analyses were pesticide quality. Solid reagents were combusted at 550°C for at least 12 hours prior to use. Sources for the reagents and equipment mentioned as well as details of the auxiliary procedures used in the extract clean-up can be found in the manual, or as referenced in the text.

PREANALYSIS PROCESSING

Sediments

Most of the sediment samples were analyzed at NERC. Duplicate runs for a number of samples were also performed in these laboratories. In all cases, the concentrations agreed within ± 15%. The first method given below is that used by J. Blazevich at NERC *(A)*, followed by the method adopted in these laboratories *(B)*.

A. The wet sample was placed in a pre-extracted Soxhlet thimble and extracted continuously for up to 36 hours with acetonitrile. After concentration the extract was partitioned with petroleum ether in the following manner. The acetonitrile extract was saturated with pet-ether and shaken with pet-ether saturated with acetonitrile. The acetonitrile layer was drawn into 2% NaCl-water (w/v), previously extracted with hexane. The remaining pet-ether layer was extracted twice more in a similar manner. The combined water-acetonitrile fraction was extracted three times with 15% diethyl ether/pet-ether (v/v), combined, passed through a sodium sulfate column, concentrated and chromatographed on 30 g of 3% H_2O/alumina (w/w) with 300 ml of 10% diethyl

ether/pet-ether. After concentration, the extract was stirred vigorously with 0.5 ml of mercury and then chromatographed on florosil (activated at 130°C) with 250 ml of 6% diethyl ether/pet ether. Following concentration of the eluant, gas chromatographic analysis was performed with a Varian 2100 gas chromatograph equipped with an electron capture detector using either an OV-17 or an SP 2401 column.

A number of blanks run during the period of analysis showed no contamination. Recoveries of PCB for each step, except for that of the extraction, were tested. An overall recovery of 95% was found. Re-extraction of one sediment sample with acetone, then pet-ether and lastly chloroform was performed. The three extracts were combined and analyzed. Less than 8% additional PCB was found, compared to the original acetonitrile extract. Gas chromatograph/mass spectrometer (GC/MS) analysis was made on several of the sediment extracts.

B. Prior to extraction the sediments were thawed and stirred thoroughly. A suitable aliquot (ca, 50 g) was transferred to a 300 ml stainless steel bottle and centrifuged at 5375 RCF for 20 minutes. The liquid layer was decanted into a glass stoppered erlemeyer flask, 30 ml of hexane added, and the mixture saved for extraction. 100 ml of precombusted (550°C) anhydrous Na_2SO_4 (Mallinckrodt, reagent grade) was added to the solid phase in the centrifuge bottle and stirred until a homogenous mixture was obtained. The mixture was then transferred to a pre-extracted Soxhlet thimble and extracted for 48 hours with a 1:2 acetone: hexane mixture.

At the end of the extraction interval the extractor was cooled and the solvent rinsed into the receiving flask; the solution was subsequently transferred with rinsing to a 1-liter separatory funnel. At this point, the water-hexane fraction saved after centrifugation was added to the funnel and the solvent washed four times with 100 ml portions of distilled water. The

water wash was collected in a second separatory funnel and the combined water washings were back-extracted with 100 ml of hexane; the aqueous phase was then discarded. All hexane fractions were combined in the same separatory funnel and washed two more times with 100 ml portions of distilled water, discarding each water fraction. The solvent was dried by passing through a Na_2SO_4 column, and the eluant collected in a 1-liter Kuderna-Danish evaporator/condenser. The sample was condensed to approximately 15 ml on a water bath.

Sample clean-up was accomplished by the standard florosil technique and the final volume adjusted appropriately for gas chromatographic (GC) analysis. Prior to analysis, the samples were treated with copper turning to remove any residual sulfur. DDT analogs interfering with PCB peaks were removed by alcoholic-KOH dehydrochlorination. The operation flow scheme is shown in Figure 1 for procedure ***B***.

Suspended Particulates and Phytoplankton

A frozen filter was thawed at room temperature, manually torn into small pieces, and transferred to a pre-extracted Soxhlet thimble. The sample was extracted with 300 ml of a 2:1 (v/v) hexane:acetone mixture for 48 hours, cooled, and the solvent transferred to a 500 ml separatory funnel. The solvent was washed four times with 100 ml portions of distilled water; the water from each washing being collected in a second 500 ml separatory funnel. The water washings were back-extracted with 50 ml of hexane and the water was discarded. The hexane layers were combined, washed twice more with 100 ml portions of distilled water, and finally dried by passage through an anhydrous Na_2SO_4 column. The eluant from the column was collected in a 500 ml Kuderna-Danish condenser and evaporated on a water bath to about 8 ml. The concentrated extract was

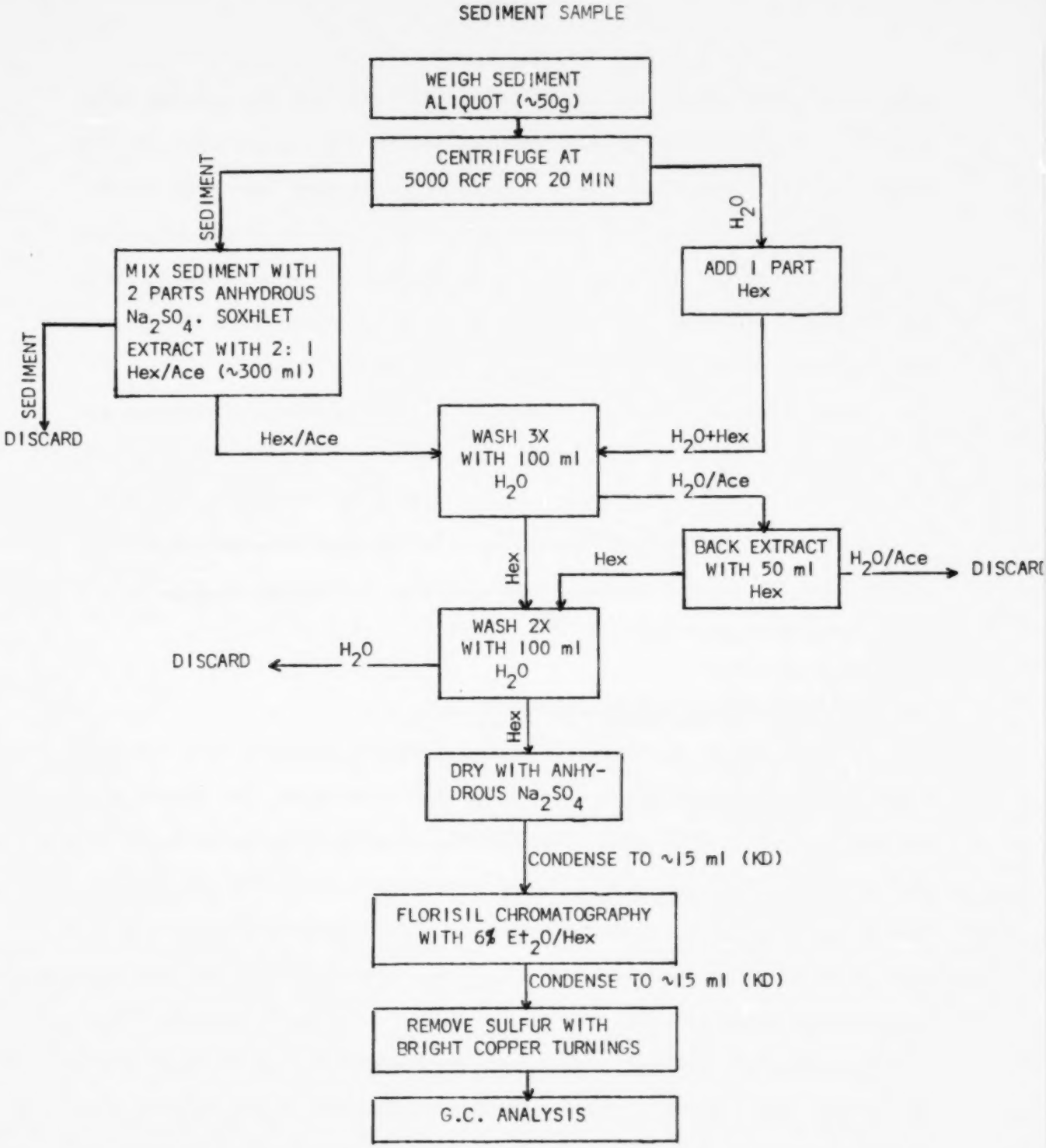


FIGURE 1. PREANALYSIS PROCESSING OF SEDIMENT SAMPLES

transferred to a 15 ml glass stoppered, graduated centrifuge tube and the volume accurately measured. 3 ml of a 1:1 (v/v) H_2SO_4 : fuming H_2SO_4 (20% SO_3) were added to the tube which was then stoppered and shaken for 2 minutes. The extract was then ready for GC analysis with the exception of adjusting the volume to obtain the proper concentration for accurate analysis. This was done with an aliquot in a separate centrifuge tube. When DDT analogs interfered with the PCB analysis, they were removed by alcoholic-KOH dehydrochlorination. The pre-analysis processing steps are outlined in Figure 2 .

Zooplankton

A modified method of Porter *et al.* (1970) was adopted for analysis of chlorinated hydrocarbons in zooplankton. The method is described below:

The sample was thawed and mixed with a metal spatula to attain homogeneity for aliquot sampling. The aliquot (10 to 15 gm wet weight) was transferred to a 50 ml beaker and the wet weight determined to the nearest 0.01 gm. It was then placed in a tissue grinder together with a precombusted (550°C) glass fiber filter (Reeve Angel, grade 934AH, 4.25 cm diameter) and ground for two minutes with 30 ml of a 2:1 (v/v) hexane acetone mixture. The solids were allowed to settle and the supernatant was passed through a glass wool plug (precombusted at 550°C) held in a glass powder funnel into a 250 ml separatory funnel. The grinding and solvent transfer were repeated three additional times and then the entire aliquot was transferred to the powder funnel. The tissue grinder and powder funnel contents were rinsed with a final 30 ml of 2:1 hexane-acetone and the glass wool plug pressed with the metal spatula to transfer the remaining solvent into the separatory funnel. 5 ml of a saturated sodium sulfate solution in distilled water and 40 ml of distilled water were then added to the separatory funnel. The funnel was shaken vigorously for one minute

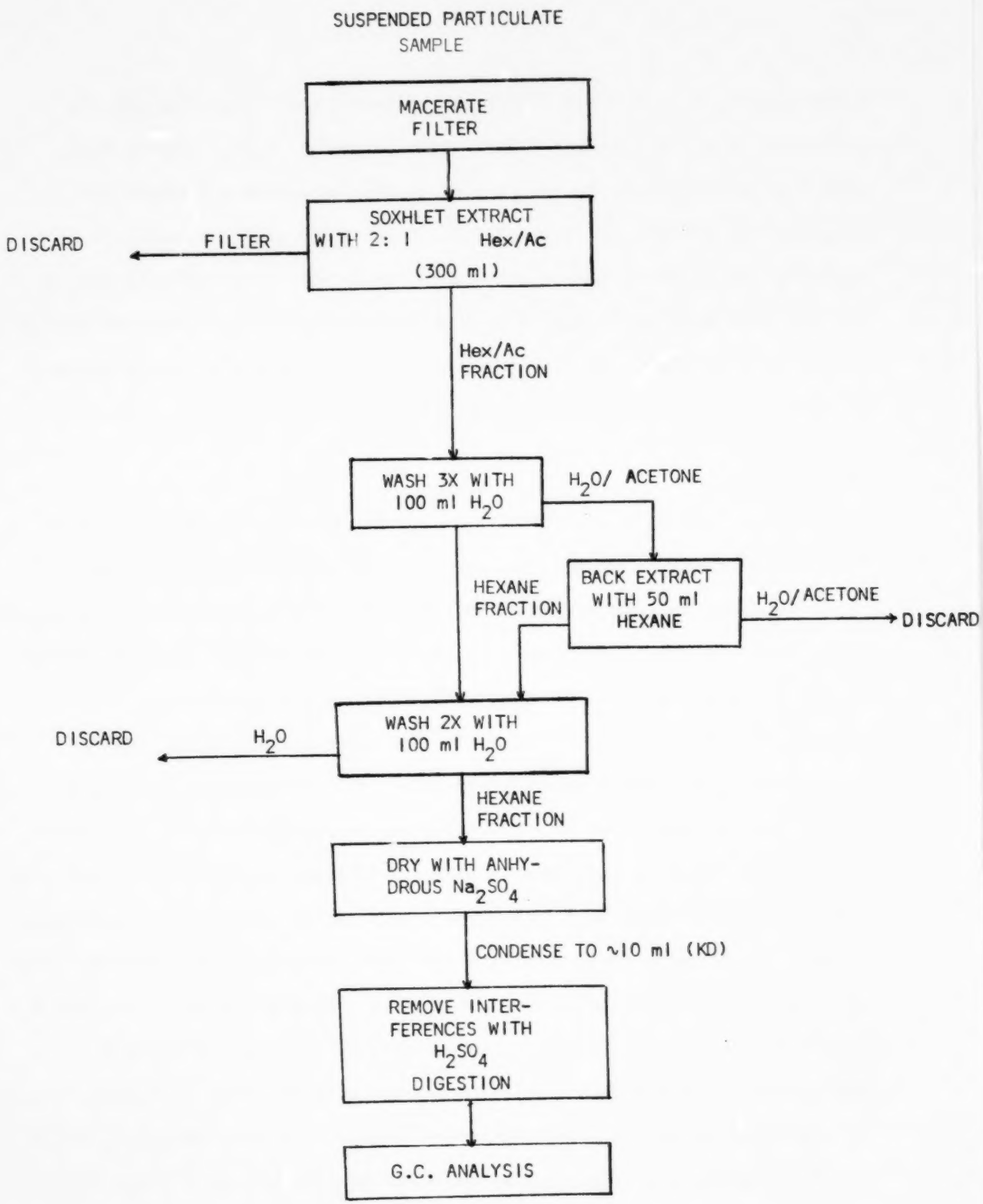


FIGURE 2. PREANALYSIS PROCESSING FOR SUSPENDED PARTICULATE/PHYTOPLANKTON SAMPLES

and the layers allowed to separate. The aqueous layer was discarded and the hexane layer was passed through a chromatographic column containing approximately 10 cm of anhydrous sodium sulfate. The column was flushed with a final 30 ml of hexane. The total column eluant was collected in a Kuderna-Danish concentrator fitted with a 3 ball Snyder column and condensed to approximately 15 ml over a water bath.

The condensate was transferred to a 25 ml Pyrex graduated cylinder and the condensate volume (V_T) accurately read. A volume aliquot (V_ℓ) of the condensate was pipetted into a 50 ml Pyrex beaker which had been dried for at least 24 hours in a dessicator and weighed to the nearest 0.0001 gm. After receiving the volume aliquot, the beaker was covered with aluminum foil and returned to the dessicator until a constant weight was achieved (usually 24 to 48 hours). The difference between initial and final beaker weights (ΔW_ℓ) was taken as lipid weight. The total lipid weight of the sample (W_T) can be expressed as:

$$W_T = (\Delta W_\ell) \left(\frac{V_T}{V_\ell}\right)$$

Following removal of the aliquot for lipid analysis, the remaining condensate was shaken vigorously for two minutes and the two layers allowed to separate. The acetonitrile was removed and the partitioning performed 3 times more. The hexane was discarded and all of the acetonitrile fractions were collected in a 1 liter separatory funnel containing 100 ml hexane, 650 ml distilled water, and 40 ml of a saturated solution of sodium sulfate in distilled water (the latter two having been prewashed with 100 ml of hexane). The 1 liter separatory funnel was then shaken vigorously for two minutes and the layers allowed to separate. The lower layer was transferred to a second 1 liter separatory funnel containing 100 ml hexane, shaken vigorously for

thirty seconds and the layers allowed to separate again before discarding the water layer. The hexane phases from both 1 liter separatory funnels were combined, passed through a sodium sulfate column and condensed in a Kuderna-Danish concentrator.

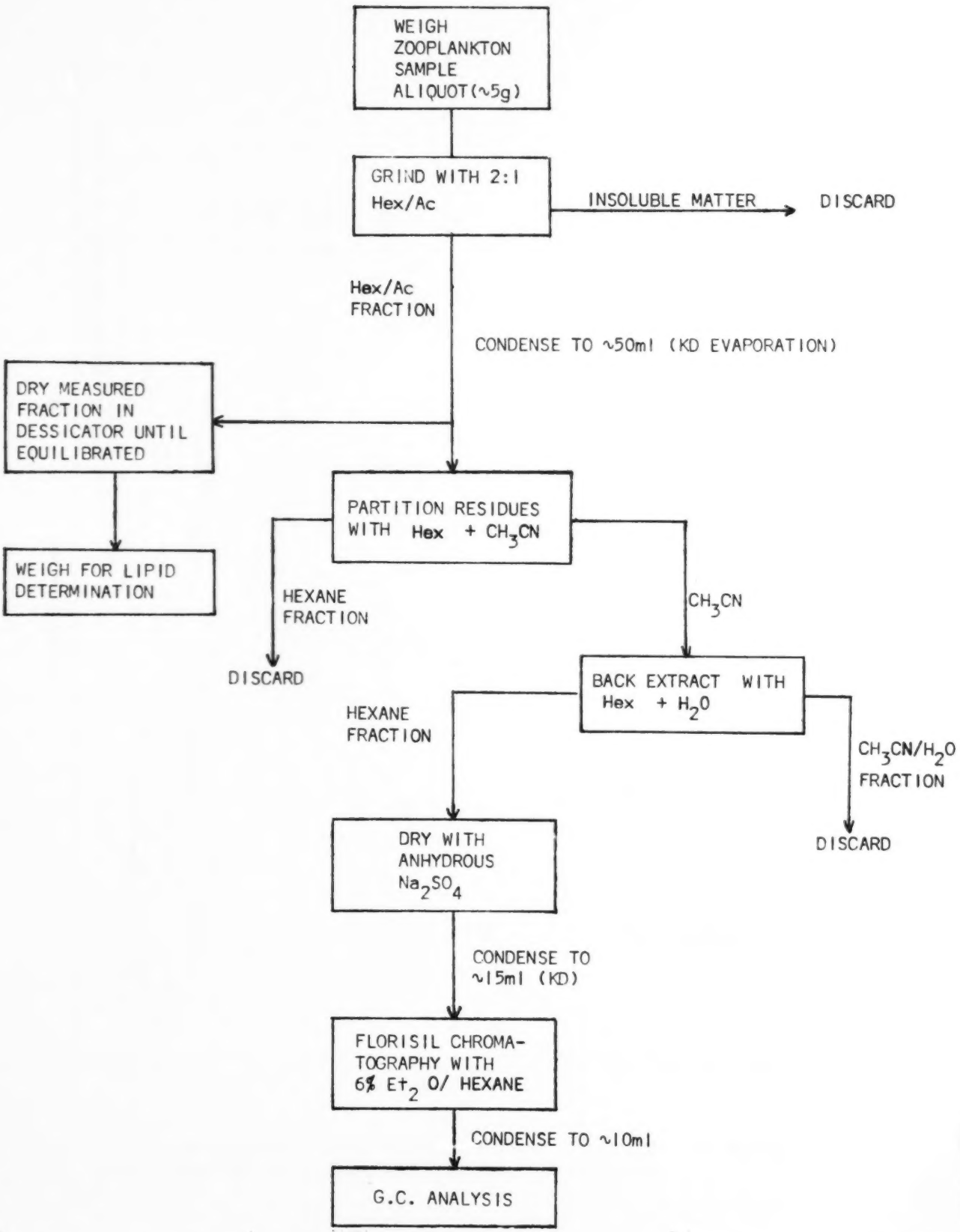
The condensate was cleaned up by florisil column chromatography, collecting the 6% diethyl ether-hexane fraction. The sample was condensed to an appropriate volume for GC analysis. Interfering DDT analogs were removed by alcoholic-KOH dehydrochlorination. The flow scheme is shown in Figure 3.

ANALYSIS

All GC analyses were performed on a Microtek MT-220 gas chromatograph equipped with a ^{63}Ni electron capture detector operated in the pulse mode (voltage, 55V; pulse rate, 270 µsec; pulse width, 3 µsec; base current, 4.5×10^{-9} amp). The carrier gas was a mixture of 90% argon and 10% methane. A 6 ft x 2 mm ID Pyrex column packed with 3% OV-17 on 100-120 mesh Chromosorb W-HP was used.

Calibrations were made with standard mixtures of pp'- and op' isomers of DDT, DDD, and DDE between sample injections. The Aroclors(R) 1242, 1254, and 1260 (Monsanto Co., St. Louis, Mo.) were used as standards for PCB calibrations. Quantitation was accomplished by the "absolute" standard method. The pesticide and PCB components present in the sample were identified by their retention times (t_r) and their structures confirmed by mass spectrometry. Typical GC spectra are shown in Figure 4. The characteristic fragmentation pattern for one of the sediment PCB components (pentachlorobiphenyl) is shown in Figure 5 (SYOPS 2, St 13).

ZOOPLANKTON SAMPLE



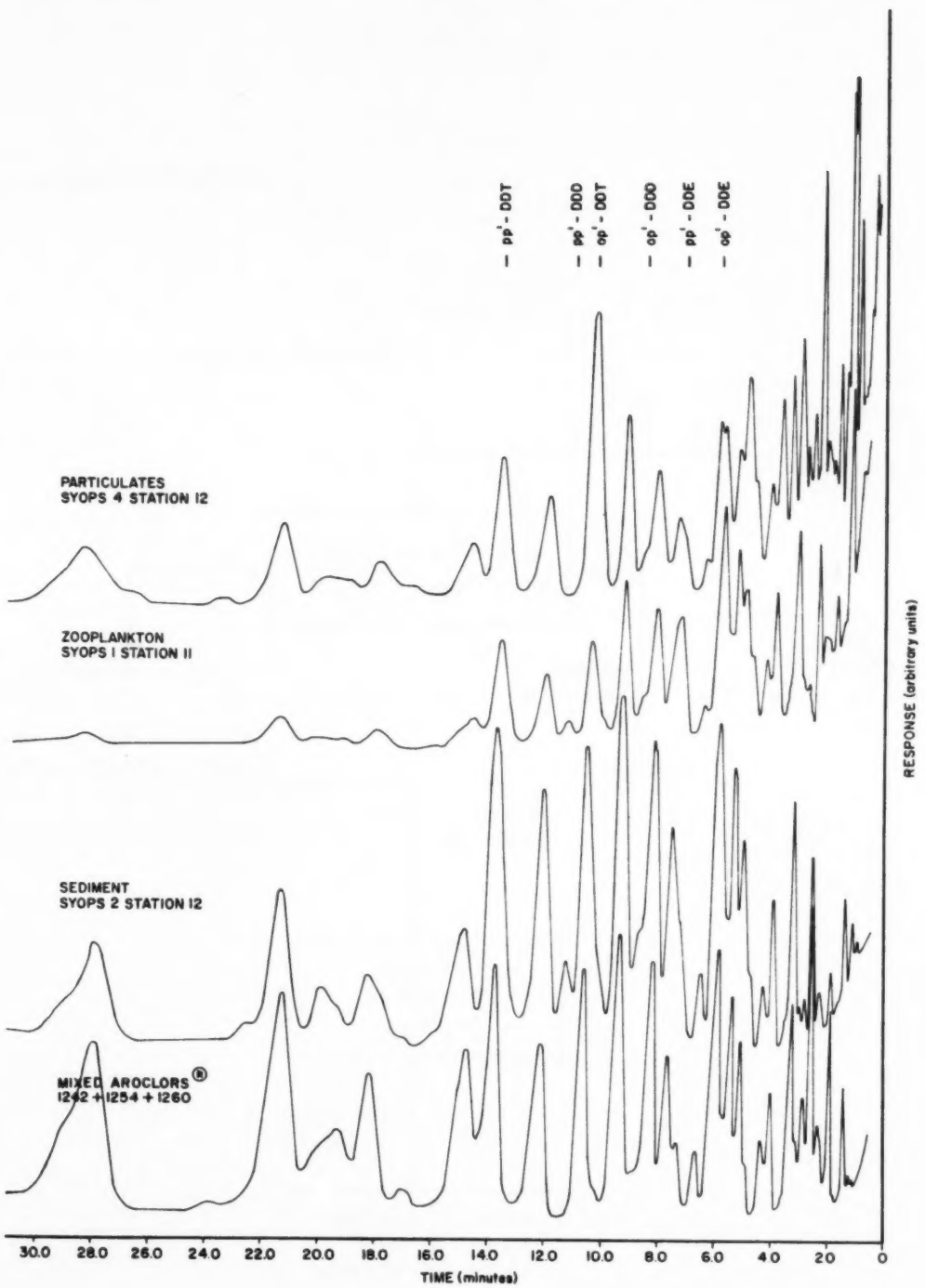


FIGURE 4. TYPICAL GC SPECTRA OF CHLORINATED HYDROCARBONS IN SUSPENDED PARTICULATE, ZOOPLANKTON AND SEDIMENT SAMPLES

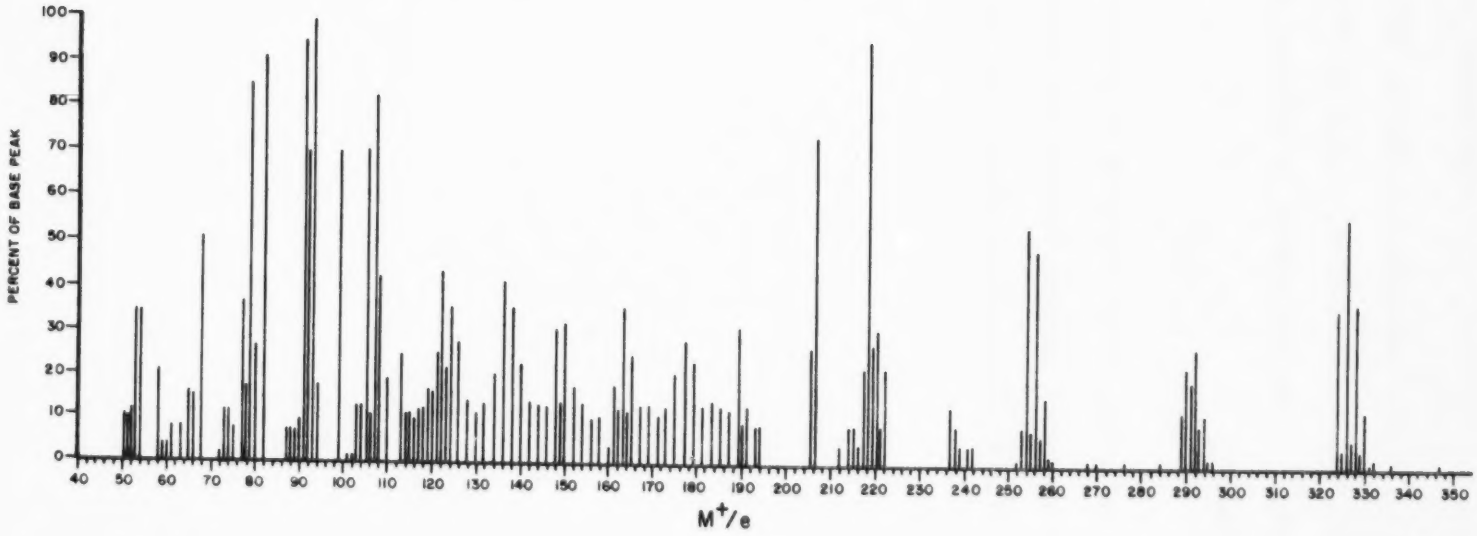


FIGURE 5. FRAGMENTATION PATTERN OF A PCB COMPONENT PRESENT IN A SEDIMENT SAMPLE OBTAINED IN ELLIOTT BAY

REFERENCES

Porter, M.L., S.J.V. Young and J.A. Burke, 1970. A method for the analysis of fish, animal, and poultry tissue for chlorinated pesticide residues. *Journal of the Association of Official Analytical Chemists*, 53(6): 1300-1303.

Thompson, J.F., *ed.*, 1972. Analysis of pesticide residues in human and environmental samples. Primate and Pesticide Effects Laboratory, Environmental Protection Agency, Perrine, Florida.